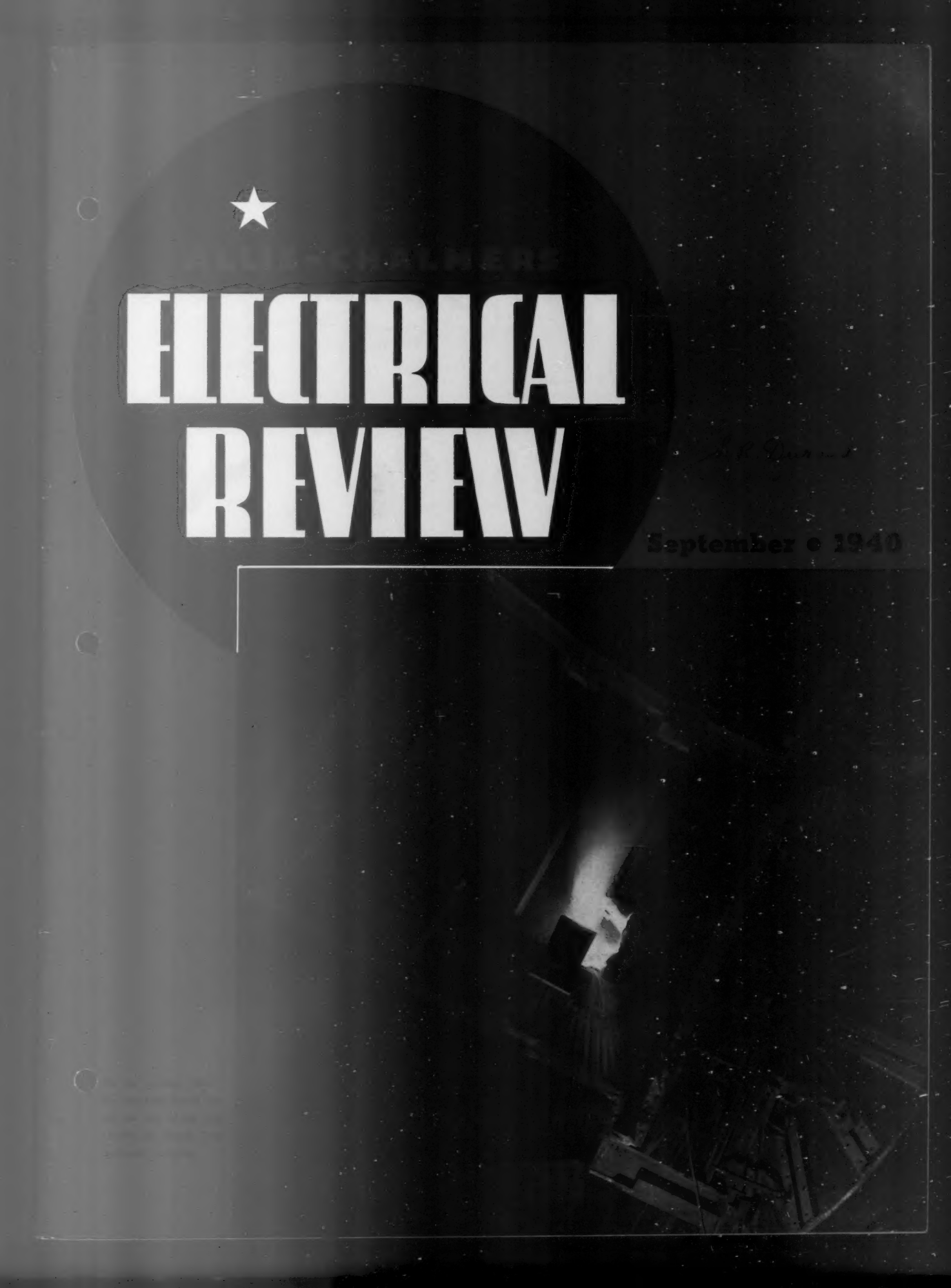
ELECTRICAL REVIEW

September • 1940



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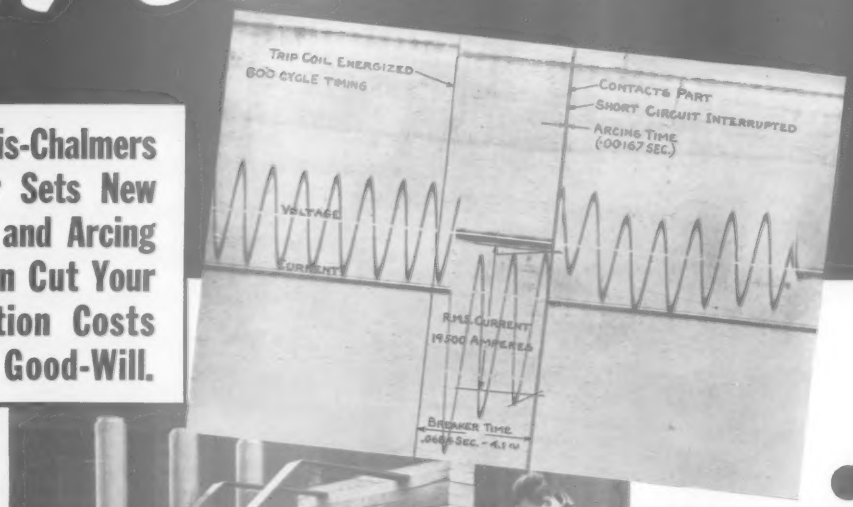

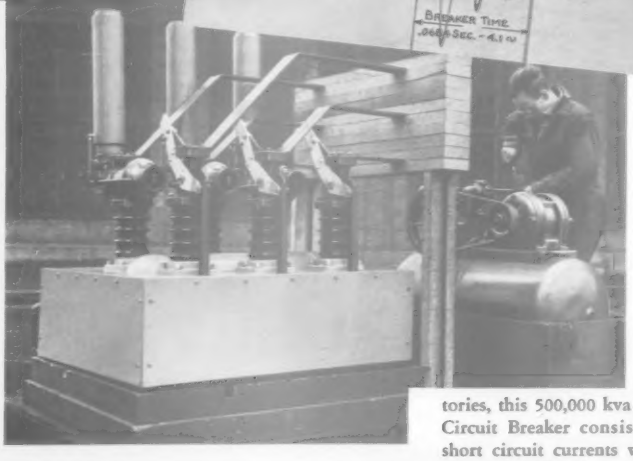

SPLIT-cycle arcing time (1/600 of a second) is shown on the oscillograph of an Air Blast Breaker interrupting 429,000 kva at 11 kv.

ON ITS way to the testing laboratories, this 500,000 kva Allis-Chalmers Air Blast Circuit Breaker consistently interrupted heavy short circuit currents with arcing times of less than one-half cycle.

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What's more, the automatic insertion of paralleling resistors dampens high frequency transients . . . improves your power factor . . . limits the magnitude and rate of rise of recovery voltage during arc interruption.

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Vol. V . . . . No. 3

September, 1940

Allis-Chalmers

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ELECTRICAL REVIEW

C O N T E N T S

Power System Planning — Chicago Style 5
T. G. LeCLAIR

Control Your Temper! 13
T. B. MONTGOMERY

0.010 Inch — 32 Gauge 20
D. B. SCOTT

What Would Compulsory Patent Licensing Mean to You? . 27
H. V. NYE and H. S. SILVER

Engineering Fundamentals 30
OPERATION OF A 25 CYCLE TRANSFORMER ON 60 CYCLES

Electricity for the Northwest 32
D. F. MISZ

POWER SYSTEM PLANNING — CHICAGO STYLE

T. G. LeClair, **Supervising Development Engineer**

COMMONWEALTH EDISON COMPANY • CHICAGO, ILLINOIS

A new science — power system planning — is fast becoming a part of our public utility systems. Here is how the Commonwealth Edison Company uses it to eliminate hit-or-miss guesswork in planning for future load demands.

Power system planning is playing an increasingly important part in the management and engineering of electric utility systems. In the earlier days of the utility industry, the improvements in equipment and in station design came so rapidly that the design of individual units occupied all of the attention of the engineers. Today electrical equipment has attained a very high degree of perfection; for example -- transformers are over 99 percent efficient, transmission lines are almost lightning-proof at the higher voltages, and relays and circuit breakers have been improved to a point where a short circuit can be disconnected within less than one-quarter of a second.

Another change that has taken place in recent years is the lessened rate of load growth. With a rapid rate of growth there was relatively less need for accurate load estimating to determine when new capacity was needed, because the load would soon use up the additional capacity, whether the estimate was correct or not. Today, with larger units of equipment and with a slower rate of increase, an error in load estimating may result in an appreciable increase in fixed charges for unnecessary plant.

To avoid the pitfalls of inaccurate estimating and to maintain the same standards of service reliability on all parts of the system, from the generator to the consumer, there has evolved a science—power system planning.

The present discussion of the system planning problem is naturally based on experience of the company with which the writer is associated. A detailed description of the methods of system planning would be unnecessarily long, because different methods are used on different parts of the electrical system. In this discussion the methods of planning will be brought out by illustrations of the procedures and results on various parts of the system.

Coordinated planning

All planning is based on a fundamental reserve policy to obtain a high standard of service. By reserve policy is meant the practice of providing equipment in excess of that needed to carry the load so that failures of equipment will not mean loss of service during the repair period. System planning must also be based on a sound method of system protection to disconnect faulty equipment with the minimum possible disturbance to adjacent equipment or customer service.

With these general policies of reserve and protection in mind, the first step in system planning is load analyzing and predicting in order that the needed additional equipment will be available in time to care for the load which is expected to appear. The second step is the determination of the system layout, which is the process of determining the relation of the sizes of transformers, transmission lines, etc., to the load to be carried in a given area and the arrangement of these units to maintain the maximum use of equipment without sacrificing reserve standards. Some of the special tools used in planning problems will be considered in detail with relation to the problems on a particular part of the electrical system.

The magnitude of the problem of system planning increases in comparison with the size of the system involved; therefore, this discussion will begin near the customer and progress toward the source of power at the generating stations.

The electrical equipment in an individual home or store obviously involves no system planning problem. There is also no system planning problem in the service from the mains in the street or alley to the customer's meter. Failures on this part of the system are so rare, the extent of the disturbance so small, and the cost of prevention so high that the provision of a spare service drop would not be economically justified. Here the system planning need not go beyond determining a few standard size units for various loads.

With a radial 4,000 volt distribution system, such as is used in Chicago, no appreciable planning problem is involved in the supply to the secondary mains serving a customer. The layout of the city is such that most blocks contain alleys, and the secondary in one alley serves all the load in that block and can be supplied by a single transformer or bank of trans-

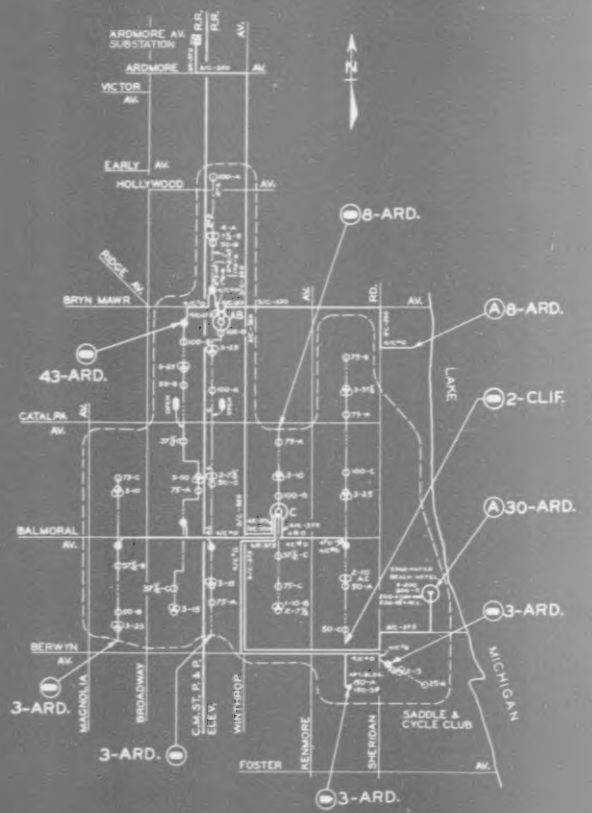
AT LEFT: Mounting the coils on the core of a three phase, transformer type, 5/8% half-cycling step feeder voltage regulator.

formers. While a short circuit in one of these transformers will interrupt service in this block, these transformer failures are likely to occur about once in a hundred years. It is practicable to replace a transformer in a very short time in a metropolitan area where no transformer is far from the district headquarters. It is also a simple matter to have a transformer permanently maintained on a truck which can be hauled to any location for temporary supply to larger loads.

Distribution system

For this 4,000 volt radial distribution system, the design of the equipment in each territory and the planning problem are so closely related that the two functions are handled in one group within the Commonwealth Edison organization. With this procedure, each portion of the city is assigned to an individual engineer who is able to maintain close contact with the territory, resulting in a continuous policy in the changes made from year to year. By individual control of territories, whereby one engineer keeps constant watch on a comparatively small territory and knows the nature of building developments which may be taking place, reasonably accurate predictions can be made of load growth.

Fig. 1—Typical 4,000 volt distribution feeder layout. The heavy lines represent underground cable; the dot-and-dash lines, overhead construction in alleys; the large circles, feeder distribution centers; the small circles, transformers; and the circles with arrows, interconnecting points for emergency supply from adjoining feeders. An inspection of the diagram shows that any part of the circuit can be supplied by some emergency feed, no matter what portion of the underground cable main or the main feeder cable from the substation may be out of service.



The 4,000 volt distribution system consists of underground cables from substations connected to overhead mains supplying the transformers in various blocks. The arrangement of this system can best be seen by referring to Fig. 1, which is a typical feeder layout. In this figure, cable runs underground from the substation to disconnecting potheads on the cable pole near the center of the territory to be served. From this point various branches extend to groups of load.

Each group of load is so arranged that it can be connected to not only the primary sources of supply but also, by means of disconnecting potheads, to an adjacent 4,000 volt feeder cable in the event of trouble. Spare 4,000 volt feeder capacity is available for every part of the city. Men in the field are constantly on duty so that, if trouble does occur, all the load can be transferred to stand-by equipment within a very short time. This method of planning provides a high standard of service without the cost of a complete duplicate supply with automatic circuit breakers.

Substations

Substations to supply the 4,000 volt distribution system may serve from two to twenty individual outgoing feeders. It is therefore considered essential to have reserve transformer capacity in these substations so that any transformer may be out of service because of trouble without excessively overloading the remaining transformers.

Figure 2 is a single-line diagram of the connections in a typical substation, showing the several transformers connected between the 12,000 and 4,000 volt buses. These transformers are equipped with circuit breakers on both the high voltage and low voltage sides and with relays that disconnect any transformer that experiences a short circuit, without disturbing the parallel transformers and without interrupting the service to any customer. It is necessary to have this reserve capacity instantly available because trouble in such large units of equipment, if it should occur, would take nearly a day to repair. An interruption of this duration caused by a transformer failure cannot be tolerated.

Substations in various parts of the city are of various sizes and are placed as nearly as possible to the load center. The number, size and spacing of these substations is an interesting economic problem within the jurisdiction of the planning engineer. It is not practicable to cover this problem in detail in this short paper. However, it is obvious that larger substations with large units will reduce the cost per kva of a substation. On the other hand, larger substations mean a larger area served per substation, and this in turn increases the average length of 4,000 volt cable to the load.

A general study has determined the most economical substation size for a given load density. Practical consideration varies this size, and the boundaries of the territory to be served by a given substation change from year to year. When two substations become fully loaded in the same year, it is possible to install capacity in only one substation and reduce the load on the other substation by shifting the territorial boundaries to transfer the load to the substation with the new capacity.

12,000 volt transmission

The same reserve policy is used for the 12,000 volt lines serving substations as for the transformer capacity in these substations. Every substation is provided with enough transmission line capacity so that any one of these transmission lines can be out of service at the time of the maximum load without exceeding the load limitation on the remaining cables. To accomplish this result economically, it is desirable to group these substations so that two or three substations may be supplied with a given group of transmission lines.

Figure 3 shows a typical arrangement of lines to supply a group of substations and also illustrates the method by which the most economical arrangement of these lines is obtained. For this particular group of substations, the load estimates indicate that more line capacity is needed to carry the estimated maximum load for the coming year. With the load distributed on several different substations and with maximum loads possibly occurring at different times of the day, it is not a simple matter to calculate the division of load on the various transmission lines, under emergency conditions with various lines out of service, to determine which line arrangement will make the maximum use of the cable capacity.

The answer to this problem is determined by setting up the electrical system in miniature on a device known as an alternating-current calculating board. This calculating board has various circuits, each of which can be set up to have its impedance exactly proportional to the impedances of the various full-sized transmission lines. A miniature source of power then supplies miniature loads. With this set-up the various emergency conditions are determined quickly by simply opening circuits and measuring the loads in the various remaining circuits, one at a time. In the illustration, Fig. 3, alternative methods of connecting the additional transmission cable were tested on the calculating board, and the one shown in plan 1 was found to be the scheme providing the maximum total useful capacity.

After the planning engineer has determined the most economical scheme and obtained an estimate of the cost of the scheme, various interested individuals of the company are informed through a "project diagram." Fig. 4 shows a typical project diagram. The heavy lines indicate the equipment to be installed as a part of this project. This diagram serves as a work coordinator to inform the designer responsible for

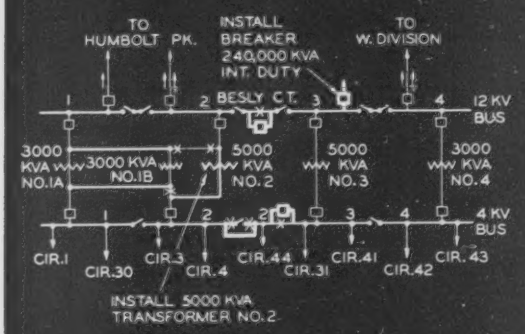


Fig. 2—Bus diagram of a typical 4,000 volt distribution substation. The diagram is in the form used for requesting an estimate of the cost of new transformer capacity. The heavy lines represent new work to be installed as a part of the project estimated.

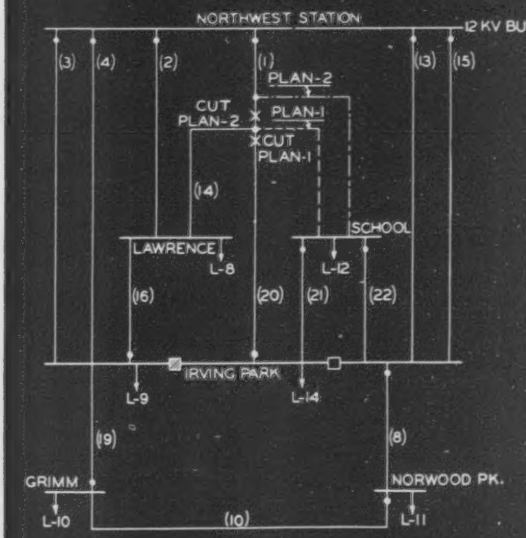


Fig. 3—One-line diagram of 12,000 volt transmission system to supply a group of five substations from Northwest Generating Station. The diagram is in the form used for setting up a study on the alternating-current calculating board to determine load division with alternative schemes for new line capacity. The numbers on the diagrams represent circuits on the calculating board used to simulate lines and loads of the actual system. The dash line and the dot-and-dash lines represent two alternative methods of connecting additional line capacity. Note that one plan results in a direct line to School Street Substation and a tie line from Lawrence to Irving Park. The other plan results in a direct line with taps to supply both Lawrence and School.

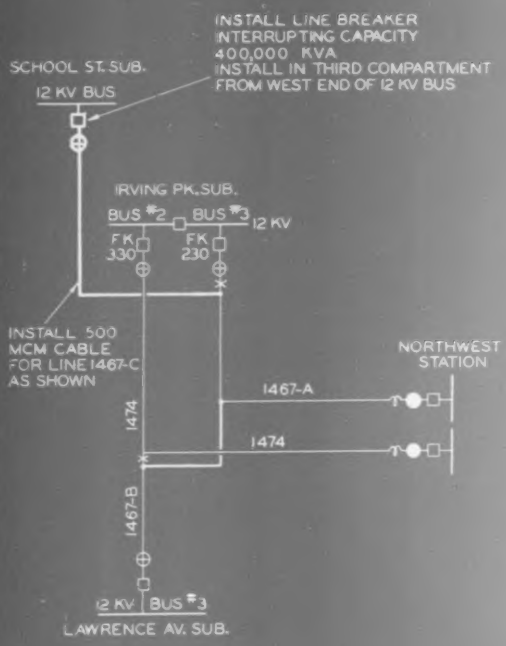


Fig. 4 — Typical project diagram. The heavy lines of this one-line diagram indicate the new work to be installed as a part of the project to increase the line capacity into School Street Substation. The work in this diagram is for the project decided upon from the calculating board study illustrated in Fig. 3.

the work in the substation that his work must coordinate with that of the designer responsible for the cable work.

A-c calculating board

The alternating-current calculating board just mentioned in solving the typical transmission line problem is a relatively new tool for system planning engineers. Fig. 5 is a photograph of the board owned by the Commonwealth Edison Company, the first to be purchased by a utility company for its own use. This calculating board is an expensive piece of equipment, but it has been worth many times its cost. The ability to solve planning problems quickly and accurately results in large savings in investment in physical plant by insuring that the system plan chosen is the most economical possible. It is also possible to solve in two hours a technical problem that might otherwise easily take two days for calculation.

Fig. 5

Fig. 5—Alternating-current calculating board. This calculating board can be used to simulate in miniature practically any reasonable part of a transmission system, including the generators and the loads. Circuits can be adjusted to have the proper amount of resistance, reactance, and capacitance, and can be plugged into any desired arrangements. Units are also available to simulate the mutual impedances between transmission lines, tap changers on transformers, etc.

Distributing stations and station switching

Most 12,000 volt lines supplying substations come from generating stations where power is generated at the same voltage, but some of these lines come from distributing stations. Distributing stations serve the same purpose as generating stations in their supply to outgoing 12,000 volt lines. However, the primary supply is from large transformer banks connected to the 66,000 volt transmission system. In either the generating station or distributing station, the 12,000 volt buses and circuit breakers are relatively expensive because large circuit breakers are required to interrupt the high short circuit currents.

It is also essential that, where so much power is concentrated, the absolute maximum of service reliability be obtained. Therefore, estimates of the load to be supplied must be quite accurate to predict the need for new capacity correctly. These load estimates are made in the following manner.

A number of different types of load are supplied from the same distributing stations. The largest is the 4,000 volt load which has just been discussed. In addition, there is the direct-current load, the load of the street and elevated railways, and the load of the larger customers served directly from the 12,000 volt system. All these loads have radically different characteristics, both as to the time of day and year when the maximum load occurs and the expected rate of increase from year to year.

Figure 6 illustrates the past and future loads of the 4,000 volt system according to the latest predictions. The estimated future load is determined by projecting the non-coincident load on all substations on the basis of both a maximum and a minimum rate of growth and then averaging these limiting assumptions. The maximum coincident load is determined by dividing into the non-coincident load a diversity factor obtained from an average of past years, unless there are special circumstances that indicate the possibility of a change in this diversity factor.

Figure 7 illustrates the difference in the expected rate of growth for various classes of load. The estimated rate of growth for the total load on a distributing station is, therefore, determined by first analyzing to find the amount of load of each class in the zone and projecting each of these classes into the future, then combining them for the estimated total load in coming years.

Determining capacities

The amount of capacity needed is determined from the load estimates on the assumption that the station must be able to carry the load with any bus, any transformer, or any circuit breaker out of service. In generating stations where the supply to the outgoing lines comes from both generators and transformers, a more liberal reserve policy is necessary because a generator may be out of service for several weeks while it is being overhauled, whereas a transformer can be replaced within a day or two. In generating stations the reserve policy assumed is that the station can carry the maximum load of the zone with the two largest generator or transformer units out of service.

Figure 8 illustrates a typical generating station bus diagram with the arrangement of the outgoing 12,000 volt transmission lines. On this diagram each of the lines going to a given group of substations is labeled with the number of the group in the center of the circle at each circuit breaker which supplies one of these lines. It is apparent from an inspection of this diagram that the lines to a given group of substations are distributed throughout the length of the bus so that interruptions of any part of this bus will not disconnect all the lines of a given substation group.

Fig. 8—One-line diagram of 12,000 volt buses in a generating station with all substations supplied from this station. Special precautions are taken to see that all lines which supply a given group of load are well distributed throughout the length of the station so that no station trouble can interrupt all lines in a given group. For example, the three lines to supply Wrightwood Substation (designated as group 5) come from three separate line buses, each of which is fed by a separate section of the main bus.

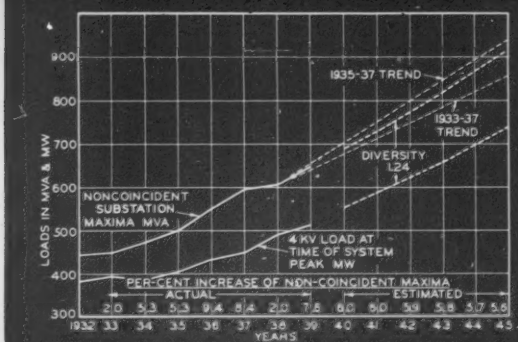


Fig. 6—Past and predicted load on the 4,000 volt distribution system of the Commonwealth Edison Company. The diagram illustrates the method of predicting future loads on both a maximum and a minimum basis, then using a compromise estimate for planning purposes. Experience has shown that the coincident load or the load at the time of system peak can be determined more accurately by obtaining it from the non-coincident load with an estimated diversity factor rather than by direct projection of the coincident loads from past experience.

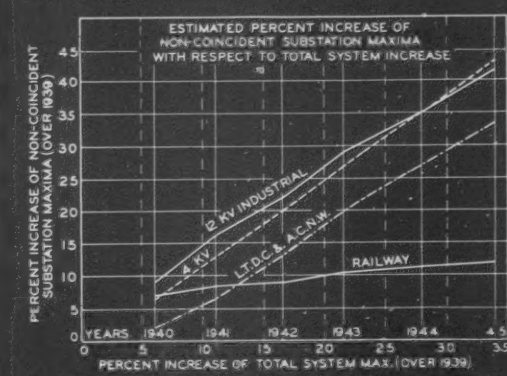

ESTIMATED PERCENT INCREASE OF NON-COINCIDENT SUBSTATION MAXIMA WITH RESPECT TO TOTAL SYSTEM INCREASE
PERCENT INCREASE OF NON-COINCIDENT SUBSTATION MAXIMA (OVER 1939)
12 KV INDUSTRIAL
4 KV
L.T.D.C. & A.C.N.W.
RAILWAY
YEARS
PERCENT INCREASE OF TOTAL SYSTEM MAX. (OVER 1939)

Fig. 7—Estimated rates of load increases on various classes of load in Chicago. This estimate indicates the striking difference between the rate of load growth of the heavy industrial and the electric railway loads.

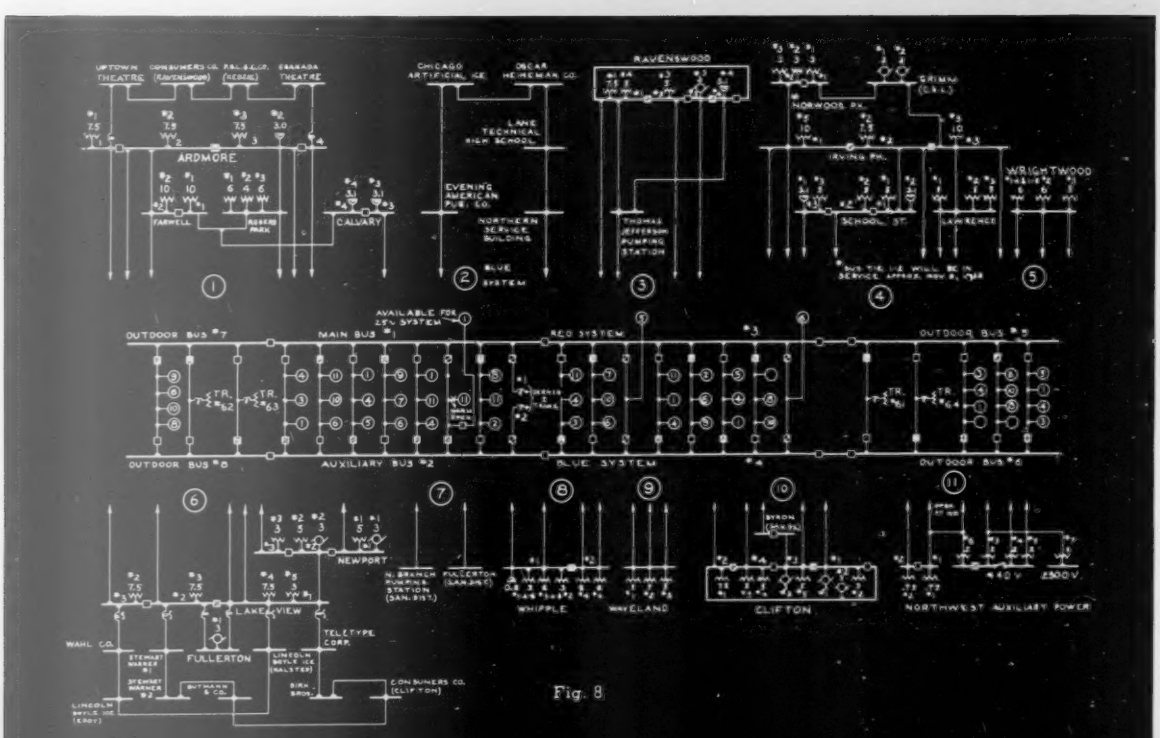


Fig. 8

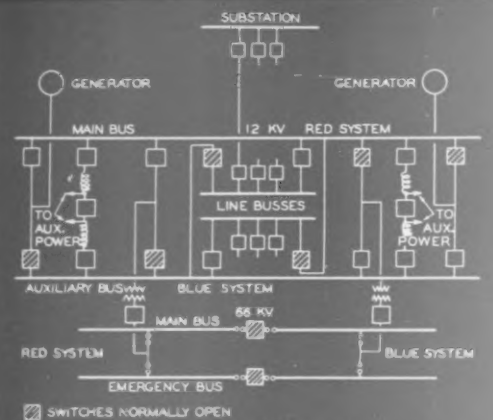


Fig. 9—Sectionalizing scheme in 12,000 volt generating station. Outgoing lines are supplied from line buses. Each line bus can be fed from either the bus on the red system or the blue system, but is normally connected to only one. In the event of any unforeseen calamity which involved the main bus on the red system all dependent load and all the supply through the generators or transformers could be quickly transferred to the other system.

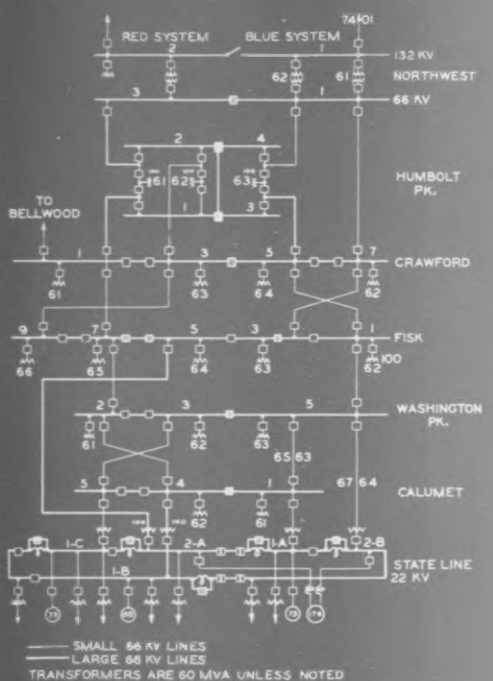


Fig. 10 — One-line diagram of 66,000 volt transmission system connecting all generating and distribution stations in Chicago. Note the division through the center of the diagram from top to bottom showing that 66,000 volt lines and buses on the right side are connected to the blue system and those on the left are connected to the red system. The cross-hatched circuit breakers are kept open so that the connection between the red and blue system is made only through the low voltage buses not shown in the diagram.

As a further insurance against serious interruptions, even though the normal means of protection should fail, each station is divided into two individual parts commonly called the "red" and "blue" buses. These two parts are operated either entirely independently or are loosely connected through breakers operated by instantaneous relays. With this arrangement, a complete failure in one-half of the station would leave the other half intact. All outgoing lines could then be quickly connected to the good half of the station with minimum delay. Fig. 9 is a schematic diagram illustrating this principle.

In this diagram several outgoing lines are supplied from a given line bus. Each line bus has a normal supply from a main bus on either the red or the blue system. A major calamity, if it should occur, would interrupt at most the load fed from the red or the blue system. In such an event the unaffected generators, lines, and transformers could be quickly transferred to the good system to restore service.

Bulk power transmission

All generating and distributing stations within the City of Chicago are connected directly through 66,000 volt underground lines so that the generating capacity in any station is readily available to all other generating and distributing stations. The number and arrangement of these transmission lines is not a direct function of the load in any given area. The need for these transmission lines is determined by the relative locations of generators and the load which these generators may serve under various emergency conditions. For example, the number of transmission lines from Crawford Station to Fisk Station in Fig. 10 would be determined by the maximum power which Crawford Station could supply toward Fisk Station, with the generators of Fisk Station out of service and with the maximum power available from Crawford Station generators after taking care of their own zone load.

This 66,000 volt system, because of its importance in the bulk power supply, is designed with a maximum reliability of each unit. All terminals are of isolated phase construction so that no short circuit can occur between phases. Since the underground lines are constructed of single-conductor cable and the transformers are single-phase units, no short circuit can occur on the buses, lines, or transformers, except from one phase to ground. A resistance is used in the transformer neutral connection which limits the magnitude of the ground fault currents to safe values for the circuit breakers. All parts of this system are provided with instantaneous relays so that any faulty piece of equipment will be disconnected in less than one-quarter second.

As a further protection, this system is also sectionalized into two parallel parts. Each of these parts is operated independently. They are not even synchronized in any station at this voltage. The only connection between the red and the blue 66,000 volt lines is through the transformers and low tension buses in the various stations, as previously discussed.

Generating capacity

Planning the need for additional generating capacity is the most complicated problem for several reasons. Load estimates must be most accurate since it takes from two to three years to install a generating unit; and the work must, therefore, be authorized this far

in advance of the anticipated need. The reserve policy is complicated because of the multiplicity of things which can interrupt generating capacity from mechanical and electrical causes and the duration of outages of generators for overhauling and repairs.

It is necessary to take into account possible interruptions in transmission line capacity in considering the reserve policy for generating stations because so much of the supply to the concentrated Chicago load comes from stations outside the city. The necessary amount of reserve generating capacity that must be provided was recently redetermined by an intercompany committee of operating officials, based on an historical study and on their judgment of the likelihood of certain possible contingencies which might arise. This reserve policy at present calls for the generating capacity to exceed the maximum load in the district by approximately the capacity of the three largest individual sources of power.

The interconnected system illustrated in Fig. 11 is so designed that generating capacity at any point in this system is available to all parts of the system. Therefore, the estimates of load for future generating capacity must take into consideration the entire load in the area. This load is estimated by an intercompany Load Estimating Committee, which compiles the estimates of load growth for each of the distributing companies. The load estimates are used by another committee, known as the Load and Capacity Committee, to study the need for future generating units and transmission lines. This Load and Capacity Committee considers the economic justification for various feasible power projects and prepares reports discussing the comparative merits of the various projects. This committee is also responsible for tentative five-year programs for future generating capacity to be installed.

The final recommendations for generating capacity are prepared by a committee of executives known as the Power Supply Committee, whose recommendations are submitted to the Board of Directors.

Coordination

The power system planning procedure consists of the following essential steps: Load estimates must be prepared predicting with a reasonable degree of accuracy the loads to be carried at all parts of the electrical system. Various schemes for supplying these loads must be considered, cost estimates made for comparative schemes, and the needed capacity for future use determined. In all planning work the maximum benefit from the invested capital can be obtained by using a consistent reserve policy from the source of power to the ultimate consumers.

The final result of system planning is the preparation of the budget for new plant investments and the coordination of work to insure that all parts of a project are completed when they are needed.

Fig. 11—Map of the Chicago district supplied by the Commonwealth Edison Company and subsidiaries. The lines shown on this diagram are 66,000 volt and 132,000 volt tie lines through which generating capacity in any station is available to load anywhere in the area.

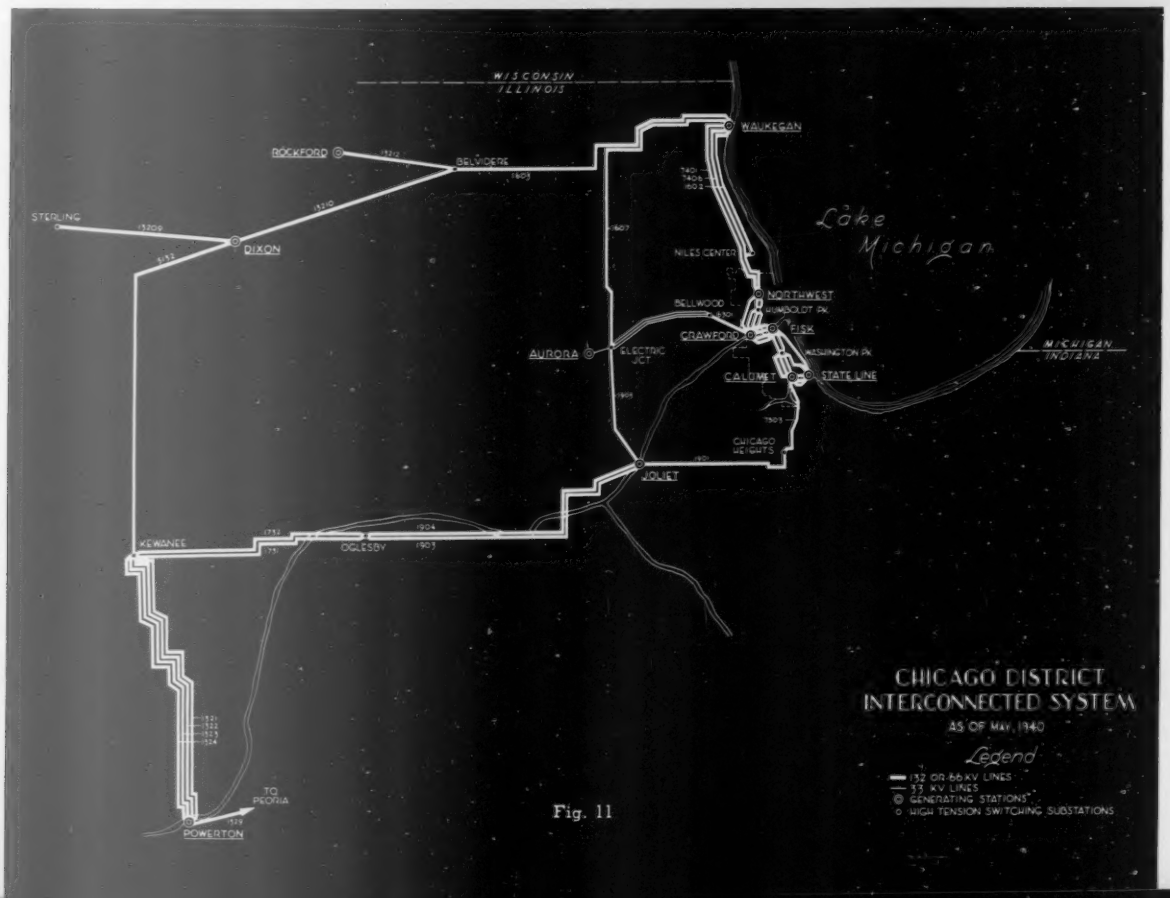
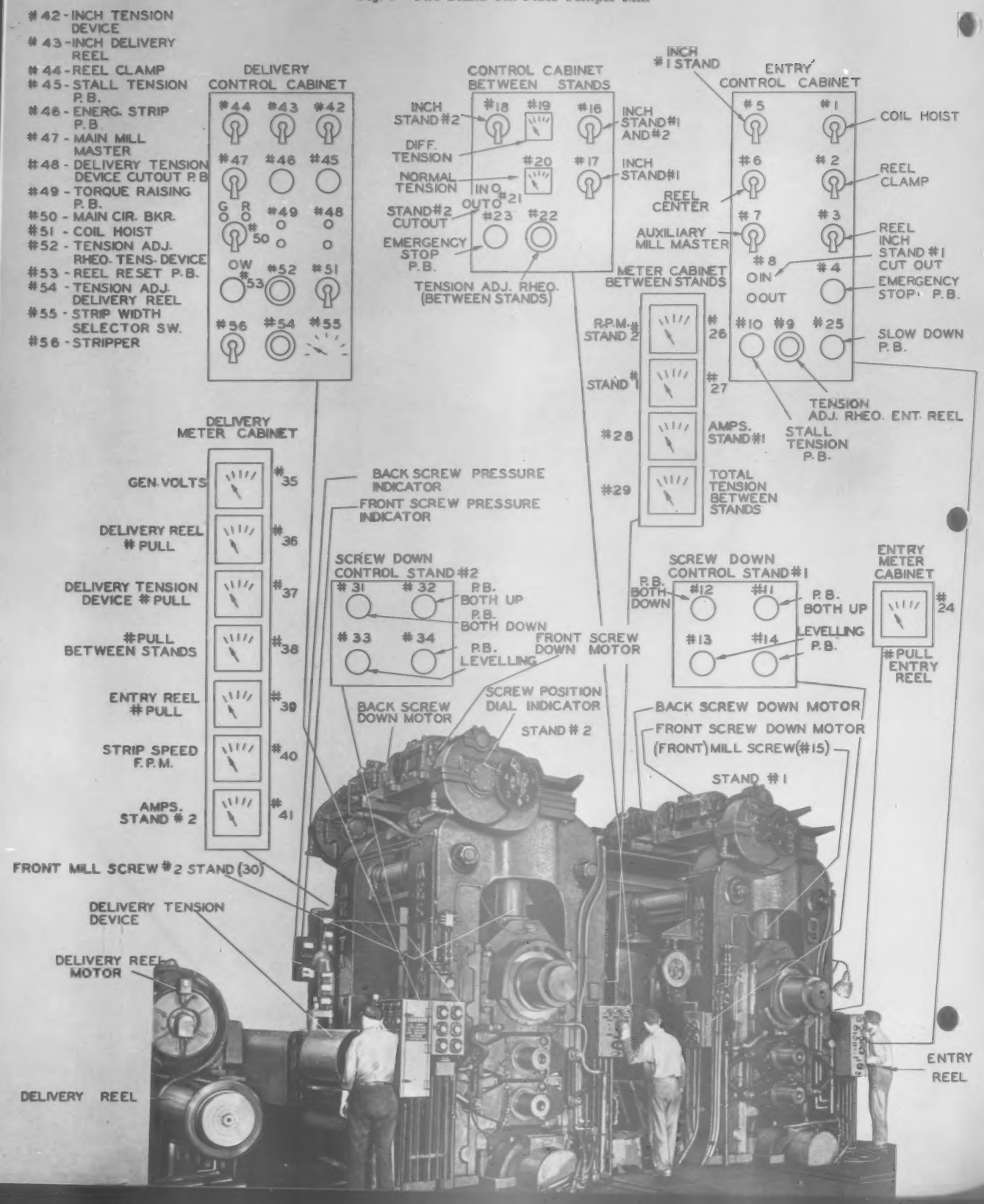


Fig. 11

Fig. 1—Two Stand Tin Plate Temper Mill



CONTROL YOUR TEMPER!

T. B. Montgomery

SWITCHGEAR DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

30,000,000,000 tin cans per year testify to the popularity of the can opener as America's most important kitchen tool. Behind this prodigious number is equipment for the precise, individual control of the temper of the sheet steel of which tin cans are made.

When steel is cold reduced, it work hardens during the process, as stated in a previous article;* that is, its elastic limit or yield point approaches its ultimate strength. Thus, when tin plate stock, normally in coil form, leaves the cold reducing mill at the desired gauge, it is very hard and brittle. In this condition, it cannot be formed satisfactorily by dies into tin cans, or the other various products for which it is used, and must, therefore, be cleaned and then annealed to reduce its hardness.

It is generally known that, after steel has been heated and subsequently cooled, it is left with a dull surface and has little elasticity or ability to "spring" without permanent deformation; in other words, its elastic limit or yield point is reduced to a low value —its temper has been dissipated.

This, of course, is far different from the condition which we are accustomed to see in the material after it has been formed into tin cans. There it has a highly finished surface and the required degree of elasticity or "spring-i-ness."

To control this elusive "temper," equipment as shown in Fig. 1 has been developed. Here the component parts of the mill are shown, as well as the control points from which the required operations are directed.

However, a better conception of the general operation may be obtained from Fig. 2, which diagrammatically shows the strip progressing from right to left through the mill.

The mill illustrated is a two-stand mill which takes coils from the annealing furnace and rolls the steel under tension to produce the desired surface finish and temper. The entry reel is used to provide back tension, which has been found to increase the effective work of the rolls of stand No. 1 which operate on the strip with relatively high pressure between rolls. This pressure is at times two million pounds or more and is distributed over the width of the strip. Likewise, tension between the stands increases the effective work of stand No. 2.

In these stands the smaller rolls in contact with the strip perform work on it while the larger rolls, termed back-up rolls, lend rigidity to the work rolls. After leaving stand No. 2 the strip passes over the periphery of the two rolls of the delivery tension device. Here the torque of the motor is transmitted to the strip only by means of surface friction between the strip and roll. The strip is then recoiled by the delivery reel.

Work performed

Except for the small percentage of torque used to overcome machine losses and bearing friction in the rolls and reels, the combined torque, produced by the delivery reel motor, the delivery tension motor and the entry reel drag generators, is entirely utilized for producing tension in the strip.

Principally because of uneven mechanical distribution of tension over the width of the coil as the reel builds up, it is not practical to produce all of the tension on the delivery end by tension on the delivery reel alone. If the strip thickness differs minutely at the edges from that at the center of the strip, this difference builds up with each succeeding lap. At increased diameter, the tension becomes uneven. Therefore, the delivery tension device is used since this provides equal pull over the whole width and pulls always in a horizontal line. The delivery tension device, therefore, makes it possible to use a relatively light tension on the reel.

However, as stands No. 1 and No. 2 do work on the strip from roll pressure, the input to the motor of stand No. 2 goes into work done on the strip, and

* "Tin Cans and American Beauties," Allis-Chalmers ELECTRICAL REVIEW, March, 1940.

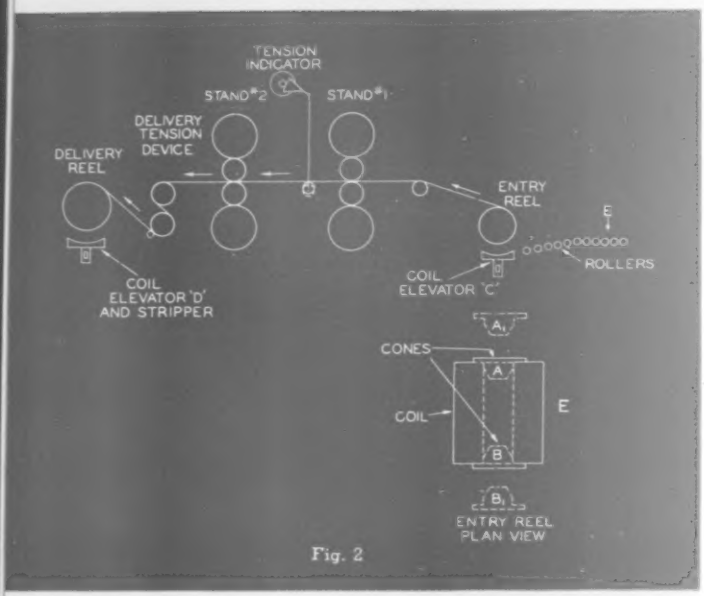


Fig. 2

a portion of it may go into the tension between the stands. The input to the motor of stand No. 1 is equal to the work done on the strip only if there is zero tension between the stands and zero tension on the entry reel or if these last two are equal in value.

The tension distribution throughout the mill is set by the operator, and the control is arranged to maintain constant tension at all operating speeds.

Acceleration requirements

The energy required to accelerate the component rotating parts is stored in these parts on acceleration and must be dissipated on deceleration. Since the mill sections are mechanically connected through the steel strip, which is under tension, to hold accurate tension during these periods, the correct amount of torque must be added to each mill motor on acceleration and subtracted on deceleration; otherwise accelerating or decelerating torque must be supplied through the strip to the motors requiring more torque from those requiring less torque. Such change in tension is not permissible because of the resulting non-uniform production. Furthermore, this change would normally cause the strip to break or become "slack" — either of which would spoil the roll surfaces and would require regrinding, which is expensive, and would interfere with production.

The higher the mill speed and the faster the rate of acceleration, the more accurately these torque values must be controlled. Also, the more difficult becomes the problem.

In Fig. 3, the normal motor torques for driving the load at any speed are represented by T_1, T_2, T_3, etc. On the delivery reel, the torque is automatically changed by the control from T_1 to T_2, as the reel builds up. Likewise, it is changed from T_6 to T_7 on the entry reel proportionally as the coil diameter is reduced in unwinding. This control function is accomplished by holding the horsepower constant at any given mill speed but causing its value for various speeds to be reset automatically in direct proportion to the speed.

The relative magnitudes of inertia in a high speed mill are represented by flywheels F_2, F_3, and F_4. These inertias can best be handled by reducing them to percentages of the full load motor torques required to accelerate them in a given time. IT_3, IT_4, and IT_5 represent the percentages of full load motor torques required to accelerate such a mill to full speed at a constant rate in eight seconds. The control is arranged to add these torques on acceleration and subtract suitable values on deceleration.

Factors affecting inertia

On the reels, however, the inertia depends on the amount of steel on them. Thus, on the delivery reel for a full width strip, the inertia is represented by the proportional size of flywheel F,F for a coil of maximum diameter, while flywheel F,E (dotted circles) gives the relative inertia for an empty reel. IT_2 represents the percentage of full load motor torque required for acceleration with a full coil and maximum strip width, while IT_1 gives this value for an empty reel. But inertia also depends on strip width. Fig. 4 shows inertia accelerating torques for various strip widths at various reel diameters. Switch 55 on the delivery control cabinet (Fig. 1) is set at the strip width being rolled, and the control is arranged to measure the reel diameter and give compensating torques as shown on the curves of Fig. 4. Like values apply to the entry reel.

All mill sections must be started at exactly the same instant. The various motors are required to develop sufficient torque to overcome static friction; and, since varying sizes of flywheels must be accelerated at the same rate without affecting the value of torque required at a steady state speed, variable voltage control is most suitable when the main mill motors are operated from the same generator. This type of control also lends itself admirably to the requirement of heavy torques at low speed. In fast accelerating mills, the torques during acceleration may approach the maximum available motor torques because of the requirements for overcoming inertia. Therefore, these considerations may determine the motor sizes to be used.

Temper control

Specified temper in the steel and surface finish is produced by a combination of roll pressure and tension in the strip. The surface finish comes mainly from

roll pressure. Therefore, the rolls of stand No. 1 and stand No. 2 are ground and polished to a smooth surface that imparts a high finish to the surface of the product.

As will be seen from Figs. 2 and 3, the normal load torques of the delivery reel and delivery tension motors and a portion of stand No. 2 motor torque, if not used completely to do work on the strip by roll pressure, add up to produce tension in the strip between the stands. This tension is balanced by the backward pull of the drag generators and that portion of the work done in stand No. 1 which is not supplied by its motor. For this reason, tension between the stands may be varied widely by variations in the energy delivered to or produced by the motor of stand No. 1. Where required, entry tension rolls similar to those in the delivery tension device shown in Fig. 2 are used between stand No. 1 and the entry reel to add to the "back pull."

As previously pointed out, the total torque delivered by the reel motors and tension device motors is used to produce tension in the strip when running at a given speed. Therefore, a measure of the motor input gives an accurate measure of the tension. On stands No. 1 and No. 2, however, the torque delivered is normally divided to go partly into tension and partly into work done on the strip by the rolls. The ratio between these components varies widely for different rolling conditions without definite relation to the value of the delivered motor torque.

Tension indicator used

Therefore, as the tension between the stands cannot be effectively measured from the electrical values of the motor input, a tension indicator, as shown in Fig. 2, is used to measure and control the tension. This device deflects the strip upward a small distance by applying a vertical force to the idler roll, and this force is converted to electrical values, measured and calibrated to give the horizontal pull in the steel.

With this arrangement, roll pressure, total tension and tension distributions between the several mill sections are under the control of the operator; and the electrical control will hold such tension values constant at any setting which he desires.

It is to be understood that this type of mill is not intended to reduce the steel in thickness or gauge but only to produce the desired Rockwell hardness, which is a measure of temper, and to give the desired surface. While acquiring these qualities, the steel undergoes a slight extension (approximately 1½ percent) in stands No. 1 and No. 2 which is incidental. In thus treating the steel the tension must be high enough to exceed the elastic limit where necessary but not high enough to approach its ultimate strength, thereby making precision control imperative.

When treated under proper tension, the steel is more even in texture and is more suitable for whatever later processes may be required in its utilization

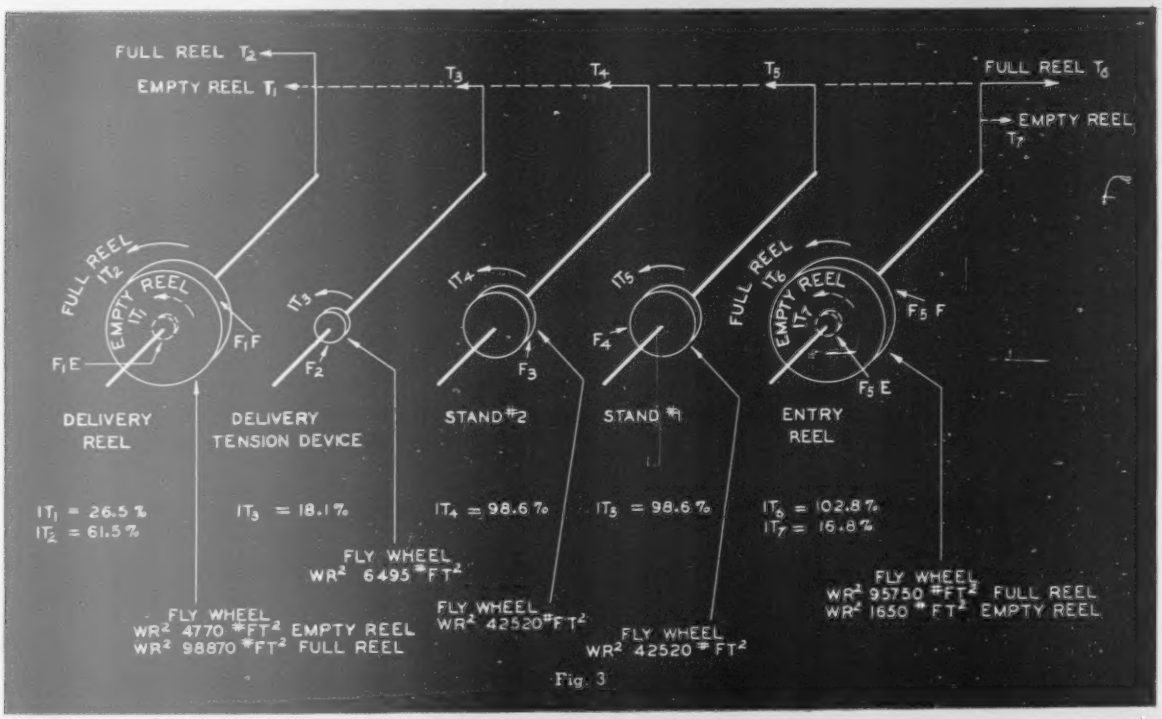


Fig. 3

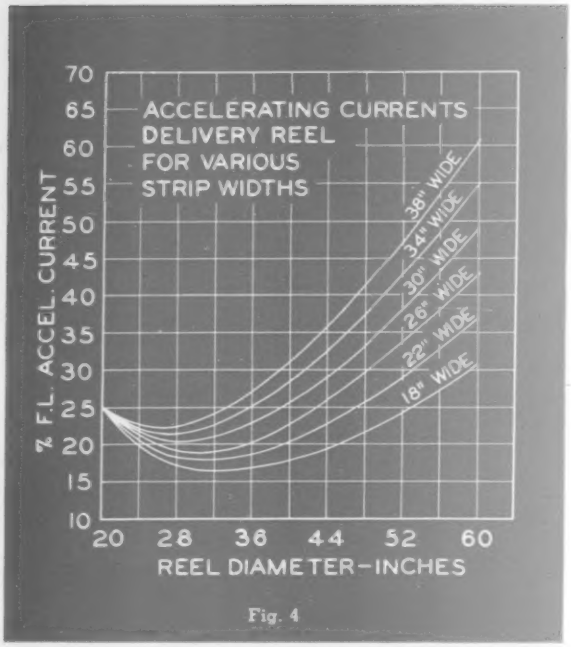


Fig. 4

than when it is tempered by roll pressure alone, as was done formerly.

Mill operations

To start a temper mill, coils are deposited at E (Fig. 2) by a truck or conveyor. The entry reel is cone type, usually with cones, as shown at A and B, connected individually to drag generators on the same base and movable axially with the cones by motor-operated racks and pinions that shift the bases when desired.

The cones are separated to positions A_1 and B_1, by means of control switch 2 (Fig. 1), which operates the motors that shift the cone bases. A coil is then rolled by gravity from E onto the hydraulic coil elevator C, where it is raised or lowered by operating switch 1, which controls the lifting cylinder, until the coil center opening is in line with the cones A and B. Then by operating switch 2, cones A and B are moved toward each other. Since they are slightly tapered they clamp the coil tightly onto their peripheries.

The elevator is then lowered to clear the coil since it is not further needed, and the coil can now be rotated in either direction by the drag generators acting as motors. Switch 3 is used for running these motors at slow or "inch" speed with full torque available, and the leading strip end is fed into stand No. 1, which is rotated similarly in either direction from switch 5 or switch 7. As the strip is being entered, switch 6 is used to move both cones simultaneously in an axial direction so that the coil is shifted and enters the end in the center of stand No. 1.

Full roll pressure applied

After the end of the coil has been entered in stand No. 1, full roll pressure is applied by means of push buttons 11 and 12, which operate the screw-down motors and turn screw 15 and a similar one on the other end of the rolls to exert pressure on the roll bearings. These motors are clutched together, but to equalize this pressure, if necessary, push buttons 13 and 14 are arranged to run one motor "up" while the other is run "down" for levelling. Where roll pressure has been applied, back tension is exerted from the drag generators by means of push button 10 and is read on indicator 24 and adjusted by operation of rheostat 9.

Similarly, stand No. 2 is rotated slowly, and the strip entered by operating switch 18; or both stands may be actuated from switch 16. Tension between the stands can be adjusted by rheostat 22 and read on indicators 19, 20, and 29. Push buttons 31, 32, 33, and 34 are used to set the screw pressures. The delivery tension device is rotated slowly by means of switch 42. The tension exerted by the tension device is adjustable from rheostat 52 and may be read on indicator 37.

These individual controls are also needed in setting or adjusting the mill, changing rolls, etc.; but normally all motors, except the delivery reel, are run slowly in the forward direction only to enter the strip from switch 7 so that the main motor operations are controlled through one switch.

The delivery reel is ordinarily of the collapsing type. In the collapsed state this reel has a "crack" in its periphery which, when the strip end reaches it, has previously been operated by switch 53 to the proper radial position to receive the strip. When switch 44 is actuated, the reel is expanded and closes the "crack" to clamp the strip. The reel is then rotated slowly by means of switch 43 to take out the "slack," and "stall" tension is applied from the reel motor through the medium of push button 45. This tension is adjusted from rheostat 54 and is read on indicator 36.

Control at delivery end

With both front and back tension on the strip, the mill is accelerated to any speed and decelerated by throwing switch 47, the main mill master, to the proper position. At this point, the whole mill is under the control of the operator at the delivery end, called the "roller"; and, through meters 35, 36, 37, 38, 39, 40, and 41, he has an indication of all the necessary mill conditions.

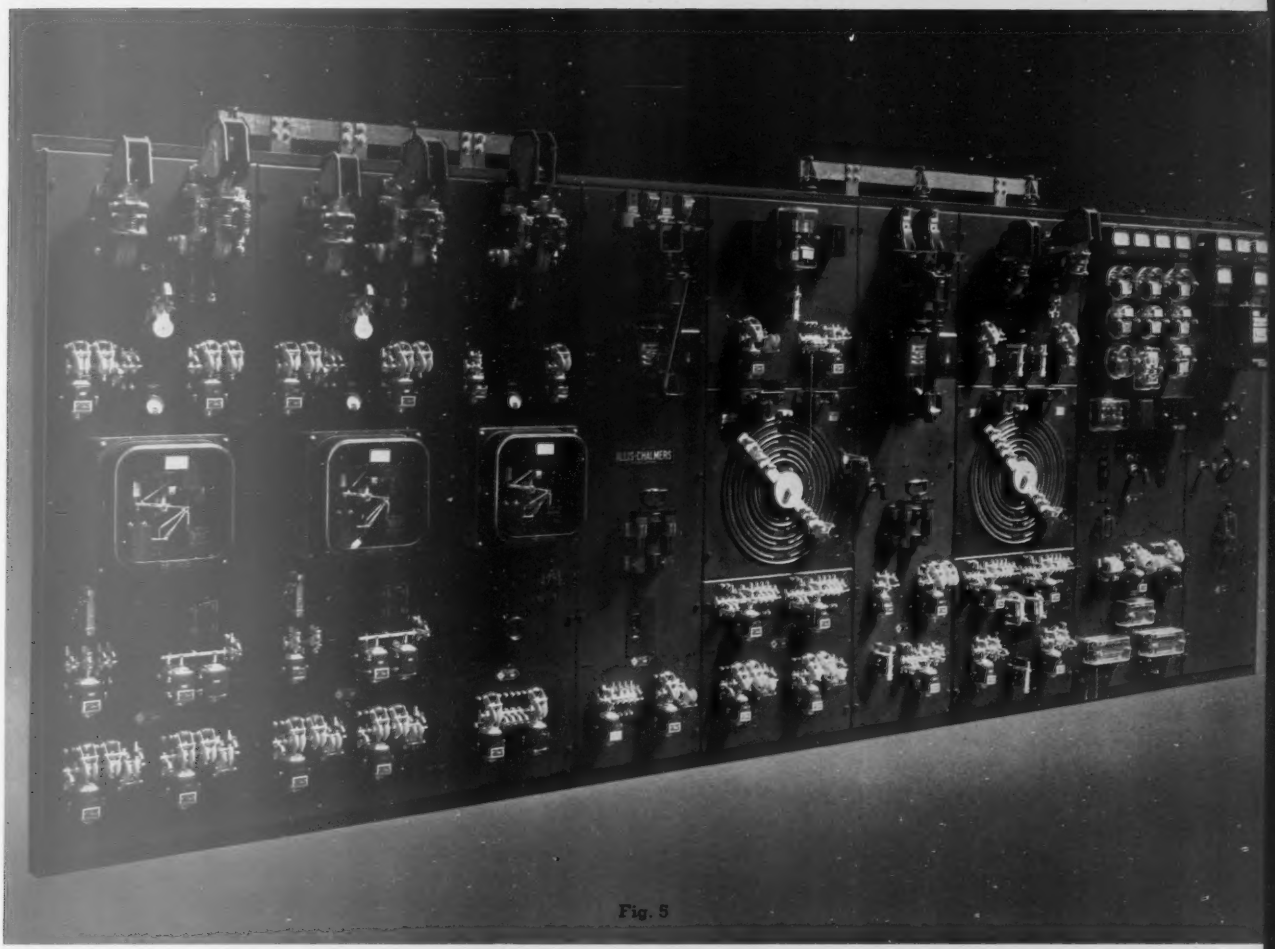


Fig. 5

At the end of the coil, the assistant "roller" at the back or entry end presses push button 25 to decelerate the mill.

To remove the coil from the delivery reel, the coil hoist is raised by operation of switch 51 to take the weight off the coil when it is collapsed by the operation of switch 44. Then it is moved off the reel axially through switch 56, and the cycle is repeated for the next coil.

If it becomes necessary to stop the mill quickly, push buttons 46, 23, or 4 are conveniently located to apply dynamic braking to bring the mill to a stop in the shortest possible time. To prevent possible injury to the operators working on the mill, the main motors can be cut out of service by means of push buttons 48, 21, and 8.

Individual, precise control necessary

As these many various operations have been found necessary and desirable under mill rolling conditions, individual motors on component mill sections and auxiliaries are most essential.

In order to hold the operating personnel to a minimum and to have operators free for maintaining quality and maximum quantity of production, precise control must be had of all machines under every condition of speed, required tension, coil size, etc.

Figure 5 shows the separately mounted electrical control which acts in response to the switches and devices described and also regulates and compensates for changing mill conditions to maintain speeds and tensions at constant or variable values required for various grades and sizes of steel.

In the case of tin can stock, after having its temper raised to the proper level, the product is sheared to the desired lengths, coated with tin, and sent on its way to be ultimately scuttled by the can opener in the great American kitchen.

ON FOLLOWING PAGES: Recently put in operation, this 25,000 kw turbo-generator is hydrogen cooled. The turbine is of the condensing reaction type.

0.010 INCH — 32 GAUGE

D. B. Scott

RECTIFIER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

That's thin, as metal goes . . . too thin for any arc welder but the Weld-O-Tron. Read this story of the new low amperage arc welder and how it works for a parade of industries — from airplane manufacturers to furniture makers.

● Although welding is a comparatively old art, having been performed over the forge of blacksmiths for centuries, the rapid acceptance by industry of the relatively new methods of welding has placed heavy demands on the designers and manufacturers of welding equipment.

Growth of welding

Early welding processes required that the metals to be joined be heated almost to the fluid state and then hammered together to form the junction. Such a process, while suitable for certain purposes, was too time-consuming and too limited in its scope to be of practical importance in the general fabrication of metals into their various forms.

However, with the introduction of oxy-acetylene and electric arc welding, the scope of application became almost unlimited and waited only for engineers and designers to recognize the possibilities of these processes and to exploit them. Today, in addition to the aforementioned methods, we have such welding equipment as the automatic arc welder, the resistance type spot and seam welder, the flash welder, and the butt welder, all of which are developments of the last few years and which are being successfully applied to new and different tasks each day.

Welding of thin sections

Only recently, advances in the design of metal products have made the welding of extremely thin sections desirable and have created a demand for equipment to handle such materials. Where the work could be accomplished by resistance welding or some similar process, little difficulty was encountered, but for work that required arc welding there was little equipment available.

Conventional arc welding equipment was designed to handle heavier work, and the lightest current welders had a minimum range of between 25 and 30 amperes and were not capable of handling materials of thicknesses less than 0.050 in. (18 gauge) with any degree of success. Industry demanded a machine that would handle materials as thin as 0.010 in. (32 gauge), and this required welding currents as low as 5 amperes.

The Weld-O-Tron was designed with this purpose in mind.

A-c and d-c welding arcs

Probably the most difficult factor to overcome in the design of a low amperage arc welding source was the necessity of a circuit characteristic that would insure arc stability. At heavy current values an arc will sustain itself during disturbances in the circuit because of the large amount of ionization between the arcing terminals, which forms a path of low resistance. At lower current values, however, this ionization of the space around the arc is considerably less and is likely to be too limited to carry the arc over any appreciable circuit disturbance.

There are two types of current source available for welding: namely, alternating current and direct current. Both were considered. However, an analysis of the problem shows that by its very nature alternating current, which passes through zero twice every cycle, represents too great a circuit disturbance to permit sustenance of a low current arc unless some means of pre-ionization is present.

Several a-c welding circuits have been introduced which make use of a high frequency current superimposed on the normal frequency of the a-c source, and this scheme has proved sufficient for the maintenance of an arc at low currents. However, a suitable and reliable source of high frequency current is rather expensive and delicate, making it necessary to search for some different solution to the problem.

Weld-O-Tron employs mercury vapor rectifiers

The solution employed in the design of the Weld-O-

Tron embodies the use of direct current supplied by a mercury vapor rectifier. It is a readily recognizable fact that a d-c arc can be maintained at very low current values if its source of supply is steady and the circuit is devoid of disturbances. The problem, therefore, resolves itself into one of providing a steady source of direct current that possesses the necessary characteristics to neutralize sufficiently the circuit disturbances normally encountered in electric arc welding.

The major disturbances to be overcome in an arc welding circuit are the effects of arc length variation caused by the operator and the effect of momentary shorting of the arc at intervals caused by drops of molten metal bridging the gap between the electrode and the work. (See Fig. 1.) Both of these factors can be neutralized by supplying a source of current which possesses a drooping voltage characteristic plus the ability to respond rapidly to changes in the circuit.

The commonest source of direct current for arc welding is the d-c generator, which can be given a satisfactory drooping voltage characteristic and which is extremely reliable. However, since it depends upon a rotating element for its operation, the generator is susceptible to changes in speed as its output varies; and, because of the inertia effect of its rotating element, there is a small time lag after each disturbance before normal speed is again attained. This change in speed is accompanied by a change in voltage and the result is a certain sluggishness in response to circuit variations. Also, because of armature reaction in the generator, the rapidity of response is hindered still further. (See Fig. 2.)

As outlined earlier, this is inconsequential at high current values, but experience has shown that, for current values below approximately 20 amperes, this slow response makes welding too difficult to be practicable. It was for this reason that a rectifier was chosen since it has no moving parts with inertia effect to be overcome and no armature reaction effect to be neutralized; therefore it is capable of instantaneous response to any changes in the circuit.

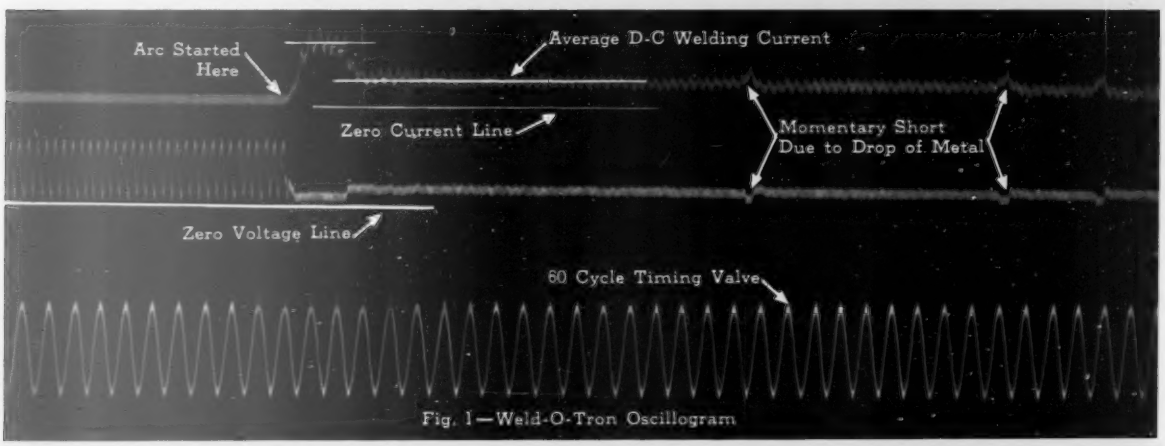
Arc voltage and current

The voltage across almost any welding arc is usually of the same value regardless of the amount of current flowing and will be found to be approximately 25 volts. Starting the arc, however, requires a higher voltage than that required for maintaining the arc, and practice indicates that a minimum starting voltage of 40 volts is desirable for ease of operation. Since a drooping voltage characteristic is required for stable operation, an open circuit voltage higher than the operating voltage is a predicated necessity, and the supplying of the proper starting voltage becomes merely a matter of proper design of the control equipment to furnish whatever open circuit voltage is desired after the proper type of characteristic is determined. Reference to the characteristic curves (Fig. 3) reveals that the Weld-O-Tron has an open circuit voltage ranging from 50 to 90 volts.

Another important consideration in the design of the control equipment is the necessity of limiting the maximum short circuit current to a value that can be handled for a limited period of time without injury to the equipment. Referring again to Fig. 3 it is seen that the maximum short circuit current obtainable is limited to approximately 112 percent of the rated output, which is considered a safe value.

The circuit

Contrary to the usual electronic circuit, where grid-controlled tubes are utilized to the fullest extent, in the design of this circuit an endeavor was made to get away from the use of grid control and to employ a control system that would ultimately produce the same results and at the same time be simpler and more economical. The solution of the problem was the three-legged saturable reactor, with an a-c coil on each outer leg and a d-c excitation coil on the center leg. Examination of Fig. 4, representing the characteristics of the saturable reactor, shows the similarity of the action of the reactor to that of a grid-controlled tube, such as an amplifier tube.


Arc Started Here
Average D-C Welding Current
Zero Current Line
Momentary Short Due to Drop of Metal
Zero Voltage Line
60 Cycle Timing Valve
Fig. 1—Weld-O-Tron Oscillogram

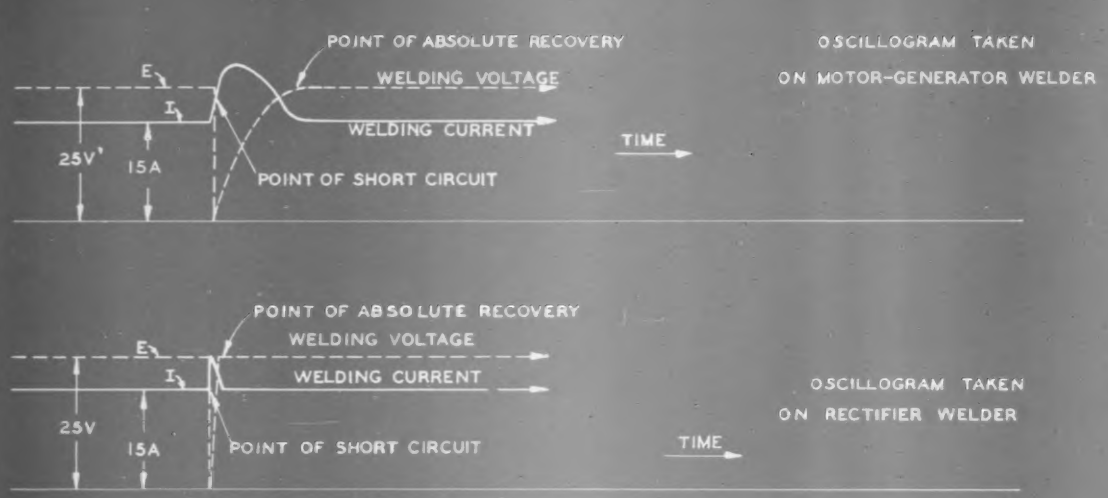


Fig. 2—Comparative Welder Oscillograms——Motor-Generator and Rectifier

Figure 5 shows the basic circuit used in the design of the welding machine and will be easily recognizable as a three-phase/six-phase rectifier conversion device. The three-legged saturable reactor is provided to give the necessary drooping output (Fig. 3) to the circuit as well as to furnish a means of control for varying the current setting.

Reactor theory

For a complete understanding of the circuit it is necessary to have a working knowledge of the three-legged saturable reactor. The saturable reactor is essentially an iron core reactor with means provided to pre-saturate the core with d-c flux. Fig. 4 illustrates the B-H or magnetization curves of the typical three-legged saturable reactor for various values of d-c saturation.

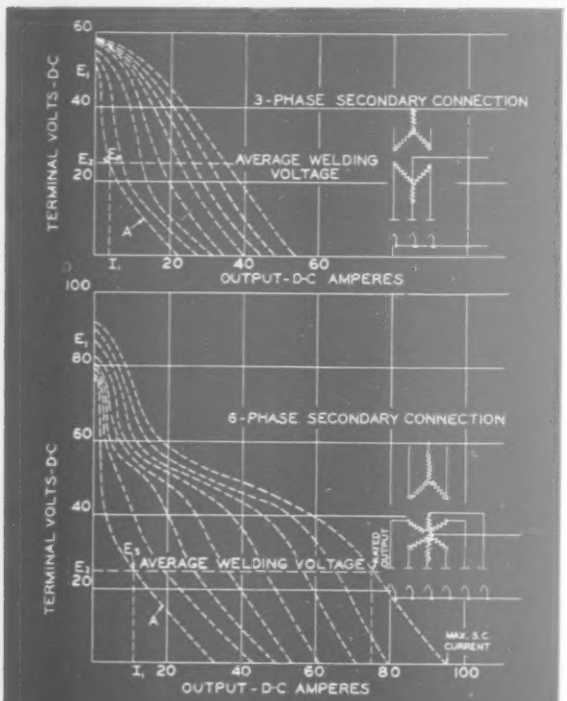


Fig. 3—Characteristic Curves of 3-Phase and 6-Phase Secondary Connections

It is clearly seen from the curves that the reactor has a well-defined magnetization curve for each different value of d-c saturation and that the impedance of the reactor can therefore be independently varied by controlling the d-c saturation current.

It is generally recognized that for all practical purposes a B-H curve can be considered as a volt-ampere curve. If this interpretation is applied to the curves of Fig. 4 (considering the abscissa amperes_{AC} instead of ampere turns per inch and the ordinate volts_{AC} instead of flux density), it becomes apparent that, for a given value of d-c saturation, an increase in the current through the reactor will cause an increase in the voltage across the reactor. Referring again to the circuit diagram of Fig. 5, it is seen that the reactor is connected directly in series with the primary of the transformers; and, therefore, any voltage drop across the reactor will cause a corresponding lowering of the voltage input to the transformer. This means that the output characteristics of the circuit are controlled by the characteristics of the reactor, and, consequently, proper reactor design can be made to yield the optimum welding circuit. Also, because of the multiplicity of magnetization curves obtainable by merely varying the d-c saturation of the reactor, it can be used for current control as well.

A common hindrance put to practical usage

In order to obtain the maximum range with the smallest possible reactor, a three-phase/six-phase output circuit has been utilized. By the use of this type of circuit, the range of a straight six-phase system is increased almost twofold. The effect is as follows:

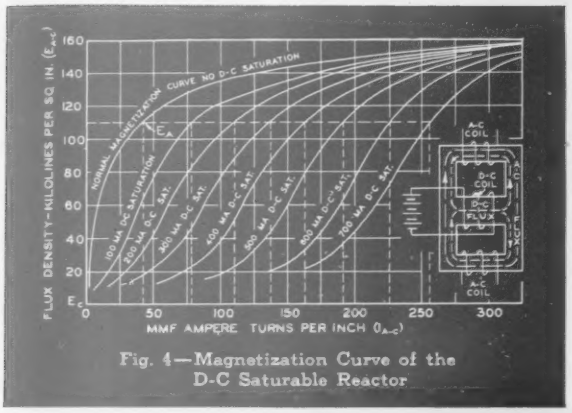


Fig. 4—Magnetization Curve of the D-C Saturable Reactor

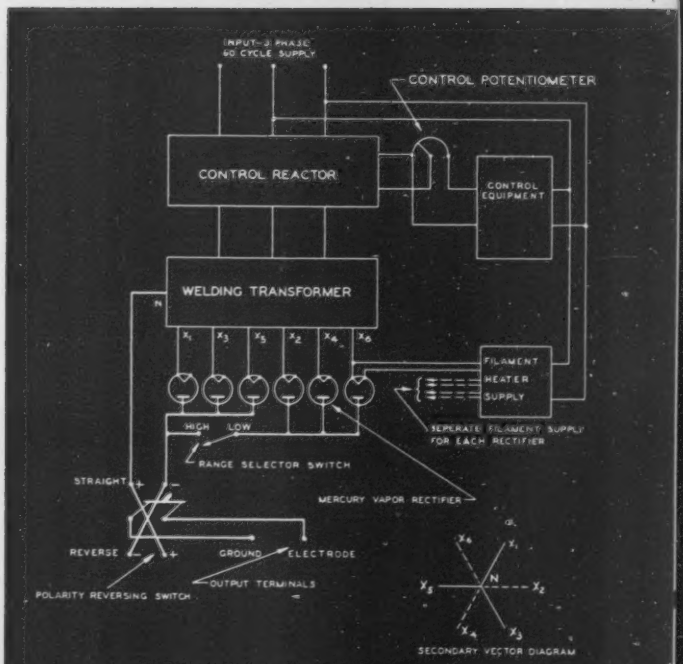


Fig. 5—Wiring Diagram of Electronic Arc Welder

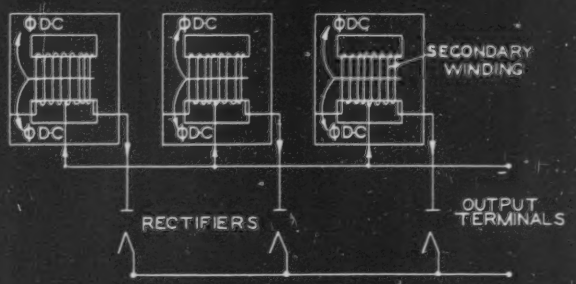


Fig. 6—Diagram of Secondary with 3-Phase Connection Showing D-C Flux

The three-phase output circuit is a straight Y-connection and will consequently cause d-c saturation in the transformer, which is usually undesirable. (See Fig. 6.) However, in this case, because of the d-c saturation on three-phase operation, the transformer will draw several times its normal excitation current and, therefore, will cause a sufficient voltage drop through the reactor to reduce the output voltage of the circuit to the operating point at a lower value of "in-phase" current than if the transformer saturation were not present.

Figure 7 serves to illustrate the effect of d-c magnetization on the normal a-c magnetizing current of a transformer. The dotted curve (1) represents the normal flux envelope due to the magnetizing current of the transformer and indicates a required magnetomotive force (mmf) of 1.2 ampere-turns per inch. The dotted line (2) represents a level of d-c magnetization for a given output. By superimposing on line (2) the dotted curve (1) or the normal a-c flux curve, curve (3) is obtained. The flux envelope is now represented by curve (3), and it is seen that a maximum mmf of 110 and a minimum of 4.5 ampere-turns per inch is required, or a net mmf of $\frac{110-4.5 \text{ NI/in.}}{2}=52.75 \text{ NI/in.}$ is now the total mmf needed to magnetize the core, as contrasted to 1.2 NI/in. with no d-c magnetization present.

The dial plate shown in Fig. 8 demonstrates the ratio of the outputs obtained by the use of the dual connection.

The rectifiers

The conversion equipment consists of six hot-cathode mercury vapor rectifier tubes. The tube is of the straight rectifier type, designed with a low temperature filament and a heavy carbon anode (Fig. 10). The filament is of a non-sagging type, and its construction is necessarily rugged in order to withstand the shocks to which portable equipment is subjected. A heavy carbon anode is used to provide adequate cooling of the anode shaft, thereby eliminating as far as possible any heat shock that would tend to crack the anode seal.

Control device

A d-c excitation source is secured from a small, full-wave, xenon-filled rectifier tube and is impressed across a potentiometer which permits manual control by allowing predetermined excitation of the reactors. The potentiometer is of the slide-wire type, thereby making possible an extremely smooth adjustment. This is particularly important on a device of this type, because the welding of thin gauge material requires very accurate current control, making variations of as little as one ampere desirable at times.

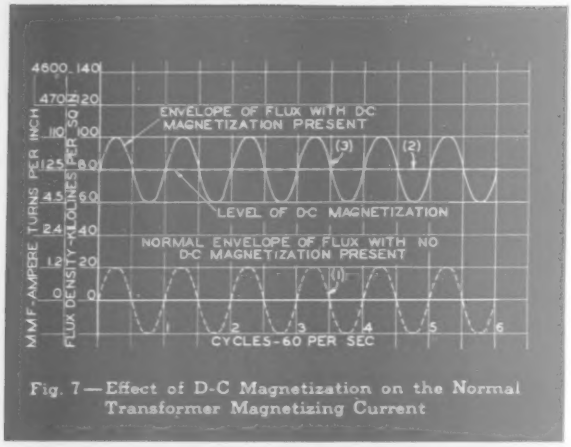

ENVELOPE OF FLUX WITH DC MAGNETIZATION PRESENT
LEVEL OF DC MAGNETIZATION
NORMAL ENVELOPE OF FLUX WITH NO DC MAGNETIZATION PRESENT
MMF-AMPERE TURNS PER INCH
FLUX DENSITY-KILOLINES PER SQ IN
CYCLES-60 PER SEC

Fig. 7—Effect of D-C Magnetization on the Normal Transformer Magnetizing Current

As outlined earlier and as shown in Fig. 8, two ranges of current are provided and are obtained by means of a range selector switch which changes the secondary circuit from three-phase to six-phase. The dial is calibrated in amperes, and two sets of calibrations are incorporated to correspond to the two settings of the range selector switch. The necessity of a voltage control device is eliminated because of the rapidity of response of the circuit to any disturbances and because of the magnitude of the open circuit voltage.

Miniature welding electrodes

Coincidental with the development of the Weld-O-Tron was the development of small diameter electrodes to facilitate successful operation at low current values. The smallest size welding electrodes formerly available were of 1/16 in. diam, and these were intended for use with current values of 25 to 40 amperes. Experimentation revealed that a 1/32 in. diam electrode was required with currents from 5 to 10 amperes, and a 3/64 in. diam electrode with currents from 10 to 20 amperes. It was found that the 1/16 in. diam electrode gave good operation at current values as low as 20 amperes.

In order to obtain suitable small diameter electrodes, welding electrode manufacturers have experimented along these lines; and there are now available 1/32 in. and 3/64 in. diam electrodes of numerous compositions, all of which give very satisfactory operation. (See Fig. 9.)

Advantages of the Weld-O-Tron

It is not the purpose of this paper to go into any of the metallurgical details of welding, but a brief description of the effects of electric arc and gas welding on two materials of similar cross section will be given to enable the reader to understand more clearly the application of the machine.

The nature of gas welding requires that the materials to be joined be heated to the fluid state with a gas flame, this flame to be moved along the edges to be joined as the weld progresses. The temperature of the common oxy-acetylene gas flame is approximately 3500 C, and the heating obtained from such a flame requires that the flame be moved along at a rate which allows considerable dissipation of heat into the metal adjacent to the weld. This dissipation of heat into the adjacent metal causes grain enlargement and its accompanying changes in the characteristics of the metal, as well as excessive surface discoloration. These factors are undesirable, and good practice attempts to eliminate them as far as possible.

Fig. 8—220-Volt Weld-O-Tron Dial Plate

Fig. 9—Sizes of Electrodes for 5 to 75 Amperes

Fig. 10—Mercury Vapor Rectifier Tube Cut to Show Filament

In contrast to the gas flame, the electric arc has a temperature of approximately 6000 C. This high temperature coupled with the electron bombardment of the metal at the joint causes immediate fusion as the arc passes, thereby allowing the arc flame to be moved along more rapidly and limiting to a great extent the excess heat to be dissipated in the material adjacent to the weld. This in turn eliminates to a certain extent the amount of grain enlargement and discoloration at the weld. Fig. 11 is a microphotographic comparison of two pieces of metal of identical physical size, each with a weld on one end — one performed with an oxy-acetylene flame and one performed with an electric arc (25 amperes). It is definitely noticeable that the grain growth stops at about two-thirds of the distance to the end of the arc welded piece and has gone all the way through the gas welded sample.

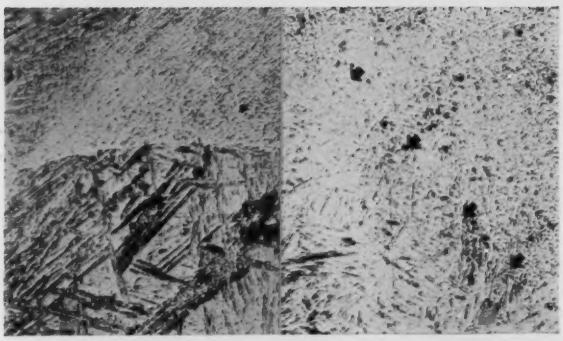


Fig. 11 — Microphotographs (enlarged 500 times) of welds of identical pieces of SAE X4130 metal 0.06 in. thick. Note the contrast in the amount and extent of grain growth between the oxy-acetylene weld (left) and the electric arc weld (right).

This same contrast can be made between two arc welded pieces, one of which has been welded with too hot an arc. Hence, its ability to furnish an arc for welding at small current values and the accompanying low heats has enabled the Weld-O-Tron to find application in every field where light gauge metal is used and especially where the nature of the work requires neat and precise welding.

Applications

The unit is useful in the aircraft industry for the fabrication of thin section parts, such as exhaust stacks and manifolds and exhaust-to-air heat exchangers for cabin heating, where sound joints are absolutely essential to prevent exhaust leaks. Electric arc welding of the structural tubing of aircraft is facilitated by the use of this unit, and general acceptance of this new method of fabrication will be forthcoming in the near future.

A demand for a low amperage arc welder has long existed in the dairy equipment field in the production of stainless steel bottling and pasteurizing machinery, as well as in the refrigeration and air conditioning industry. Fig. 12 illustrates a welder fabricating a plate for a milk cooler, with a completed cooler shown in the background. Fig. 13 illustrates the fabrication

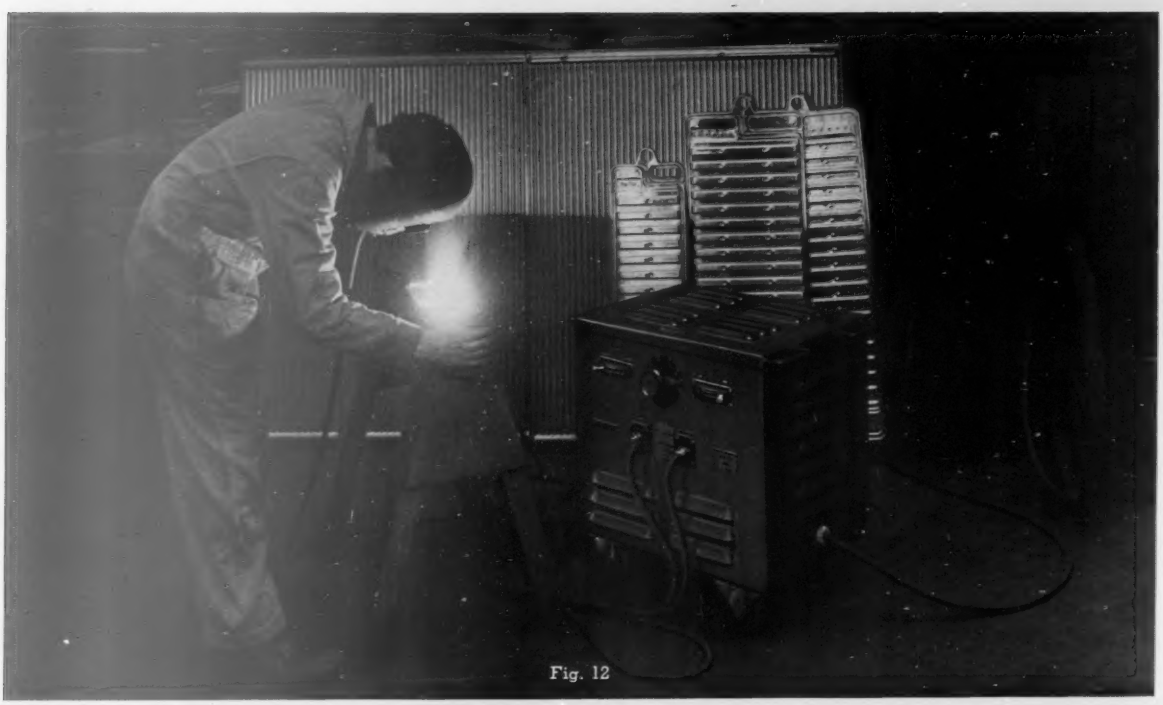


Fig. 12

Fig. 13

of cooler compartments for the interior of commercial refrigerators.

The manufacture of steel furniture has been aided to a large extent with the advent of this unit since it allows arc welding instead of gas welding on very thin sections with the consequent lack of distortion because of excess heating. The advantage of this process is especially apparent on equipment employing large, light gauge panels. The unit also lends itself well to the fabrication of tubular structures.

In job welding shops, where every kind of welding from repair of steam shovels to bicycle parts is done, the electronic arc welder has broadened the range of application to enable the operators to take on more varied and smaller types of work. It was in such job welding shops that light gauge steel fabrication, especially of the stainless type, was formerly brazed or even soldered because of the inability to produce a satisfactory weld. This handicap was also experienced by the makers of restaurant and kitchen equipment. Fig. 15 shows a stainless steel sink made from 22 gauge sheets of welded construction fabricated with the Weld-O-Tron.

The Weld-O-Tron has become invaluable as a maintenance tool in large production plants where machinery, guards, etc., have to be repaired, and in large oil refineries for patching of pipes and filters. Probably one of the most unusual applications of the unit has been in the blading of steam turbines, an application which is, incidentally, being utilized to a consistently increasing extent.

With the advent of high pressure boilers and accompanying high pressure turbines and "topping" turbines a few years ago, manufacturers of this equipment were confronted with the task of finding new materials and new methods of manufacture in order to produce machinery that would stand up under the more rigorous conditions imposed upon it by higher pressures and temperatures. It was for the solution of this and similar problems that the Weld-O-Tron was originally used. Through its use on turbine blading, the machine became known in various quarters, and demand for it arose. The success of the first few installations brought about its commercial development and eventual introduction to other industries.

The possible uses for the Weld-O-Tron, in addition to those already apparent when the machine was developed, are so varied that they cannot all be recognized and exploited at the present time. However, the development of the Weld-O-Tron has extended the scope of arc welding equipment and may open up entirely new possibilities and change present methods of fabricating thin metals.

WHAT WOULD COMPULSORY PATENT LICENSING MEAN TO YOU?

H. V. Nye, ENGINEER-IN-CHARGE, SWITCHGEAR DIVISION

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ALLIS-CHALMERS MANUFACTURING COMPANY • MILWAUKEE, WISCONSIN

Congress considers legislation that might be interpreted as a limitation of free enterprise. Here are some salient facts of what compulsory patent licensing would mean to the inventor . . . to business . . . to the public.

Hearings have been held and much discussion had as to proposed congressional action* regarding compulsory licensing under patents. Representatives of Small Business pointed out that enactment of such a law would destroy their last fortification against being swallowed by Big Business. Big Business foresaw its utter ruination in that Small Business would obtain the benefits of the successes in its vast research and development without payment for the failures inherent in such a program. The patent attorneys were divided as to their reasons for believing compulsory licensing undesirable—some had Big Business clients; some had Small Business clients.

The wee, small voices of the two geese that lay and hatch the golden eggs of invention—the inventor and the consuming public—were unheard in the general clamor.

It is believed desirable to consider possible compulsory licensing under patents from the viewpoint of the public; for, after all, it is the public that in the final analysis foots the bill. The inventor's angle is also of interest in view of the simple fact that, no inventors—no inventions.

Assumed provisions

In order to consider generally the advantages and disadvantages of a compulsory license provision from the standpoints of inventor and public, it is desirable to start with a definite premise. We shall therefore assume that any compulsory license law would include the following provisions.

1. A non-exclusive license to be granted under any patent, independently of the desire of the patent owner, to an applicant meeting the requirements laid down by law.

2. A provision for determination of a reasonable royalty rate to be paid the patent owner for use of the invention.

3. A provision insuring adequate financial responsibility on the part of the proposed licensee.

Many other specific provisions could also be included and considered; however, they would more particularly affect the manufacturer rather than the public. Let us, therefore, consider the possible advantages and disadvantages of a license law as above outlined.

Advantages

First, the right to make use of any meritorious and valuable patented invention would be insured to the public, independently of the whim of a patent owner. Inventions of great benefit to the public could not be withheld from utilization for reasons based entirely on considerations other than that of public welfare.

For example, a washing machine for domestic use is invented, utilizing a new and improved (so far as washing machines are concerned) drier for the clothes. Two shallow basins, one inverted over the other, have their adjacent edges easily locked together by a simple movement of a locking lever. The upper basin has a sheet rubber diaphragm across it. An operating lever clutches in a small air compressor which applies pressure above the diaphragm, the compressor being automatically shut off when the pressure reaches 35 pounds per square inch. The clothes in the lower basin, whether one towel or four sheets, are pressed dry with no wear or tear on the clothes or the nerves or fingers of the operator. Movement of the locking lever toward the opening position permits the air to escape with a noise that, by its immediate cessation, indicates it is permissible to open the drier.

We can all agree that such an invention would be of great benefit to the public because of its safety features, its lack of revolving rollers or centrifugal

* "Views on Patent System Changes" — I. M. Jones, Allis-Chalmers ELECTRICAL REVIEW, September, 1938.

Under compulsory licensing of patents, inventions could not be withheld by the owner from utilization by the public. For example, the manufacture of washing machines, like the one shown above, may, at present, be prevented by the owner of a patent for some feature such as the dryer.

action, and its resultant low maintenance cost and simplicity of operation. However, if a patent were adversely owned covering perhaps some single feature of the drier itself, perhaps conceived and used for an entirely different purpose, and if no license could be obtained thereunder at a reasonable royalty by a washing machine manufacturer, the public would be deprived of these greatly desirable features for the life of such patent.

It is true that it is the public that rewards the inventor by granting the right to prevent others from manufacturing, using and selling the invention, and does so in return for a published disclosure of the invention. However, this exclusive right should not be misused so that it works injury against the grantor of such right. Compulsory license would insure against such injury.

Adequate supply assured

A second advantage of compulsory licensing would accrue from the adequate supply of a patented article. If the inventor, or one manufacturing for him, were unable to supply the existing demand or were unable to provide an increased and therefore cheaper supply, other manufacturers would be moved to take out a license and market the product.

The third advantage is perhaps of greatest interest from the public standpoint. Under the proposed law an inventor who has perfected a valuable improvement may be unable to manufacture and market such improvement because of basic patents obtained by the inventor of a device which is a commercial failure. Cases have arisen where the merits of an invention have been lost to the public merely because an invention both practical and useful could not be utilized because of a prior patent which of itself could not meet the needs of the trade. This condition has sometimes diverted the entire course of development of an art away from promising directions, all entirely to the detriment of the public.

It is true that a willing cooperation between individuals in a group of manufacturers would in some cases avoid the above condition. An example of such cooperation is seen in the automobile and aviation industries where certain classes of inventions of one manufacturer are used exclusively by him for only a short period, but are thereafter available for use by any of the other manufacturers in the group. Willing cooperation between competing manufacturers might permit standardization of certain costly parts of a device for interchangeable use by all such manufacturers, thereby permitting such parts to be manufactured cheaply enough so that their use can be universal. It is to the detriment of the public generally that similar examples of willing industrial cooperation are not more numerous.

Might increase inventor's return

A fourth advantage of the above proposed law has to do with the financial return to the inventor. As we all know, the basic price for any patent is $1,000,000.00 — at least any inventor believes his invention to be worth that amount. If the royalty return in a license agreement is not commercially reasonable, the licensee will of course attempt to design away from the patent. Many inventions are not used because of the exaggerated values put thereon by the inventor, culminating in excessive royalty rates. If the inventor were compelled to accept a reasonable royalty rate, it is believed that his return would be greater in dollars and cents than if he were permitted to grant licenses at excessive royalty rates. In other words, a reasonable royalty would stimulate use of the in-

vention and therefore payment of royalty to the inventor.

A further advantage to the public of the proposed law is that a manufacturer would be prevented from withholding an improvement in his product merely because of the commercial advantage to him of continuing his present product. If the field of such product is controlled by patents, a manufacturer or group of manufacturers can do this. A compulsory license law as above outlined would prevent "dog in the manger" tactics.

Disadvantages

Under the proposed law an inventor would lose a part of his exclusive right, and in the case of a particularly meritorious invention he would be prevented from obtaining a financial return therefrom greatly in excess of what the law has set up as a reasonable return. The really great inventions are few and far between, and possibly the advantages to the greater number of inventors would compensate for the disadvantages to the comparatively few.

It is possible that if a patent owner were compelled to issue a license to any financially responsible applicant, such licensee would manufacture a product of such an inferior nature that it would injure the reputation of the product as manufactured and offered by the inventor. This practice perhaps would militate against the wide use and acceptance of the product and would therefore injure the inventor.

A third disadvantage might be that an inventor-manufacturer would be unable to build up a particular line through monopoly due to basic patents and improvements. While this may be a disadvantage to a particular inventor, it may be an advantage to the public generally.

A fourth disadvantage of considerable interest would be the possible loss by an inventor of control of the processes ancillary to manufacture and sale under a license. For example, the invention of irradiating milk, as covered by the Steenbock patent, is of great value to the public. The use of such invention is susceptible to considerable commercial buncombe on the part of irresponsible manufacturers and salesmen. Under the present law, the owners of the Steenbock patent can control the methods of advertising and the publicity blasts of the licensees under the Steenbock patent. Under a compulsory license law, such control might be lost to the patent owner.

Relative merits

In reviewing the above advantages and disadvantages, it appears that the advantages to be gained by the proposed law would be very desirable from the standpoint of the public. If we accept the premise that the real purpose of issuing a patent is to insure that an invention is made available to the public, the above advantages appear to be very desirable. If, at the same time, the inventor is aided in obtaining an adequate return, the public generally makes a greater gain. In considering the above disadvantages, it may be that, by suitable provisions in the proposed law, protection could be provided against improper use of the invention that might injure the reputation of the product.

Except for the possible loss of ancillary control over the licensed product, the possible disadvantages of compulsory licensing appear to be overwhelmed by the probable advantages, when considered from the standpoint of the public.

Through its ownership of the Steenbock patents, the Wisconsin Alumni Research Foundation is in a position to prevent its licensees from making misleading claims in their advertising and selling of irradiated products, the most important of which is milk. Such control would be threatened by compulsory patent licensing.

ENGINEERING FUNDAMENTALS

Operation of a 25 Cycle Transformer on 60 Cycles

● When a 25 cycle system is changed over to 60 cycles, it may be desirable to use the old transformers for 60 cycle service, generally without change in voltage or connections.

This changeover will affect the operating characteristics of the transformers, particularly such factors as kva rating, no-load loss, exciting current, copper loss, impedance, and temperature rise. The insulation strength on 60 cycles is the same as on 25 cycles.

When a transformer is operated at 60 cycles, the induction in the core is 25/60 of the induction at 25 cycles. The core loss at the reduced induction at 60 cycles varies with the kind of iron in the core and its original induction, but in general it will be approximately equal to 55 percent of the 25 cycle loss. The exciting current for different designs will vary still more widely, but an average figure will be 15 percent of the 25 cycle exciting current.

The I^2R loss in the copper for the same kva will be the same in both cases. The eddy current loss will vary as the square of the current. Consequently, the 60 cycle eddy current loss will be equal to $\left(\frac{60}{25}\right)^2$, or 5.76 times the 25 cycle eddy current loss.

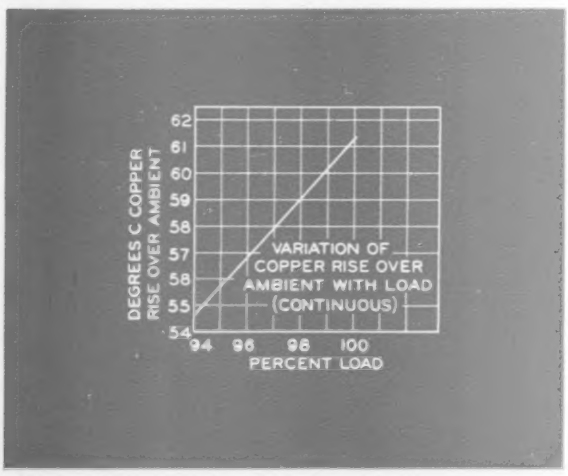
The reactance will increase in the ratio of the frequencies, or will be equal to $\frac{60}{25}$ or 2.4 times the 25 cycle reactance. The impedance can be calculated from the percent resistance (100 times the copper loss divided by the kva) and the percent reactance. The percent impedance is equal to

$$\sqrt{(\%\ \text{Resistance})^2+(\%\ \text{Reactance})^2}$$

If the transformer is self-cooled, the oil temperature rise will vary as the 0.8 power of the total loss. The temperature difference between the copper and the oil varies in a complex manner which is different for each design of transformer. However, for copper loss slightly in excess of full load, where R is the ratio of the copper loss at load L_2 to the loss at load L_1, an approximate equation is

Temperature difference between copper and oil for load L_2 = R (temperature difference with load L_1) + 10(R − 1).

A further limitation of the allowable load at 60 cycles is sometimes present when the lead currents are large. The heating of the outlet leads due to eddy currents may limit the maximum load current which can be carried. (The 60 cycle eddy current loss in the leads is 5.76 times the 25 cycle eddy current loss.) Similarly, the heating of the transformer cover due to the 60 cycle magnetic flux may be a limitation when the outlet currents are large.



Example

A transformer to be changed over to 60 cycles has the following rating and characteristics at 25 cycles: 2000 kva, single-phase, high voltage 13,200, low voltage 2300, 55 C rise, core loss 10 kw, exciting current 5%, copper loss at 75 C 20 kw, I^2R loss at 75 C 19 kw, total loss 30 kw, impedance 4%, oil rise 40 C, copper rise 55 C.

Core loss = .55 × 10 = 5.5 kw approx.
Exciting current = .15 × 5 = 0.75% approx.
Eddy current loss = (20 − 19) 5.76 = 5.76 kw
I^2R loss = 19 kw
Copper loss = 19 + 5.76 = 24.76 kw
Total loss = 5.5 + 24.76 = 30.26 kw

Reactance at 25 cycles =

$$\sqrt{(4)^2-\left(\frac{20\times 100}{2000}\right)^2}=\sqrt{15}=3.87\%$$

Reactance at 60 cycles = 2.4 × 3.87 = 9.3%

Situated on a Nebraska river is this hydro-electric plant; total generating capacity of its three turbines — 42,000 kw.

Impedance at 60 cycles=

$$\sqrt{(9.3)^2+\left(\frac{24.76\times100}{2000}\right)^2}=9.38\%$$

$$\text{Oil rise}=\left(\frac{30.28}{30}\right)^{.8}\times40=40.3\text{ C}$$

$$R=\frac{24.76}{20}=1.238$$

The copper rise over oil at 60 cycles equals $1.238\times15+10\ (1.238-1)=21$ C. The total copper rise over the ambient temperature $=40.3+21=61.3$ C.

By calculating the rise for several loads and plotting points on a curve, the load which will result in 55 C rise can be determined. For example, the following points are calculated as given above.

Percent Load	Copper Rise
100	61.3
98	59.0
96	56.8
94	54.6

From the curve, it can be seen that the 55 C rating of the transformer is $.944\times2000=1888$ kva, or 1900 kva in round numbers. The exciting current on this base $=\frac{2000}{1900}\times.75=0.79\%$ approx. The copper loss $=\left(\frac{1900}{2000}\right)^2\times24.76=22.2$ kw. The percent impedance $=\frac{1900}{2000}\times9.38=8.9\%$.

Summary of constants

To find the characteristics of a 25 cycle transformer when operating at 60 cycles, multiply the 25 cycle values by the following factors.

Quantity	Factor
Insulation Strength	1.0
Core Loss	0.55 approx.
Exciting Current	0.15 approx.
I^2R	1.0
Eddy Current Loss	5.76
Percent Reactance	2.4

The temperature rise and kva rating for 55 C rise can be determined by methods described in the text.

W. C. SEALEY.

ELECTRICITY FOR THE NORTHWEST

D. F. Misz, **Distribution Engineer**

PUGET SOUND POWER & LIGHT CO. • SEATTLE, WASH.

Rich soil . . . irrigation . . . dry farming — what have these to do with a power system? You get the answer in this article.

● Careful planning of transmission, substation, and distribution facilities of power systems which supply rural territory in the Northwest has ultimately resulted in economical and satisfactory service. The conditions under which power systems operate in this section of the country are of interest because they are a representative cross section of rural systems in other sections.

The rural territory supplied by the operating companies in the Northwest can be divided roughly into three general classifications, as follows:

A — Rich soil areas, usually without irrigation, where farms average about five acres under intensive cultivation. Houses average about ten to twenty per mile, with a high percentage of cooking and water heating load and with small power load, brooders, etc.

B — Highly productive irrigated areas, using considerable power for pumping in addition to that for domestic use. Houses average about five per mile.

C — Dry farming or less productive areas in which the farms are of considerable size, with principally domestic and small power loads. Houses average one to five per mile.

The present practices in serving the three classes of rural territory are outlined on page 34. The accompanying table shows the features of four typical systems in the Northwest.

Transmission

Transmission voltages are governed largely by the requirements of loads in cities and towns and will, undoubtedly, continue to be so governed for a number of years in the future. The use of lower transmission voltages for the heavier loaded Class A territory indicates that the larger number of substations required for this class of service makes it economically practical to use a special secondary transmission voltage. Problems of voltage control which arise from the use of these lower voltages, especially in localities of high load density such as may be found in areas adjacent to large cities, sometimes offset the savings realized in the lower substation investment. Extreme care should, therefore, be exercised in the selection of a secondary transmission voltage.

The double source of transmission supply predominates for the Class A and Class B territories, either by the use of duplicate lines or the loop system, while single lines are the rule for Class C loads. Service continuity plays a more and more important role in rural service because of the almost universal use of radios, refrigerators, electric pumps, and other appliances. Thus it is found that, when justified by the revenue, the utilities plan their systems to give maximum continuity of service.

Transmission switching for all classes of rural service is largely manual and will probably continue so until the loads justify the more expensive automatic switchgear. An infrequent outage of from 15 to 30 minutes while manual switches are being manned and operated does not as a rule cause any great inconvenience in the rural areas.

Substations

The prevailing type of distribution substation is the outdoor wood-pole variety although the trend is now toward the use of the steel structure. The advantages of steel are, of course, its improved appearance, long life, small labor cost for erection, and nearly 100 percent salvage in case of removal. Because of the small labor costs, the steel substation is very little more expensive than the wood-pole substation.

In the past, a large number of wood-pole structures have been used in rural areas. The transformers and associated equipment are mounted on a platform 18 feet above the ground and step down from a secondary transmission voltage of 13,000 to the distribution voltage of 2300 or 6900 volts. However, with service continuity and good voltage regulation being demanded on such a large percentage of the rural lines, requiring the installation of reclosing oil circuit

breakers, regulators, by-pass switches, etc., it has become difficult to provide the necessary space on platforms at a reasonable cost. Therefore, the use of steel substations with all equipment located on the ground has been favored during recent years. If and when additions are necessary, it is a simple process to extend the structure the required amount to provide the necessary additional space.

Distribution

A high percentage of rural distribution is in the 6900 volt delta and 11,000 volt star class. With the greater load densities now encountered and the close voltage regulation demanded, this voltage is found to be far superior to the 2300/4000 volt class. Substations can be spaced farther apart, and no operating difficulties which cannot be corrected by the use of modern equipment are encountered. The tendency during recent years has been to cut over rural 2300/4000 volt lines to 6900/11000 volts; and, as time passes, the lower voltage lines will be largely eliminated.

The Northwest territory uses practically no primary and secondary networking, and very little use is made of primary ties between substations. The scattered character of load and comparatively small revenue in the Class B and C territories would probably make networking too costly, but systems in at least a portion of the more thickly populated Class A territory should be suited to networking. Radial systems are easily and economically converted to networks by gradual stages and provide voltage regulation and service continuity consistent with the modern demands of service.

Primary ties between substations can sometimes be used to distinct advantage to remedy voltage troubles or improve service continuity. A description of the method used to satisfy a recent complaint, while not pertaining to a typically rural load, might serve to illustrate the advantages which may be expected from primary ties between substations.

Power was supplied to a 300 hp wound rotor type induction motor used on a coal mine hoist. This motor started under load from 12 to 15 times per hour and caused severe voltage fluctuations. In addition to the fluctuations, the 11 miles of 13 kv line serving the load passed through a heavily wooded section of country, and outages caused by falling trees were quite frequent during stormy weather. A second 13 kv line, 18 miles long, served from a different substation, was used as an emergency source of power for the mine load; and, while service continuity was better on this second line, voltage fluctuations were still too great and affected lighting loads to such an extent that the second line could not be used as the permanent feed for the mine.

However, by the simple process of connecting the two 13 kv lines together through a set of fuses, thus paralleling the two substations, it was found that the voltage fluctuations were decreased from a maximum of 16 percent to a maximum of 5 percent. During storms, the hazardous 11 mile line would be automatically disconnected by the fuses in case of trouble, leaving the mine still operating on the 18 mile line. Therefore, a substation tie solved a voltage and service problem at a cost far less than would have been required for any other method.

The use of automatic reclosing feeder switches and fused primary branch lines indicates the trend toward better service continuity. Very little use is made of the common neutral for both primary and secondary although its popularity is increasing. Because of the large number of grounds required for the common primary and secondary neutral, there are sometimes numerous interference troubles with rural telephone systems; and, until such time as this difficulty can be corrected, use of a common neutral undoubtedly will be somewhat restricted.

Capacitor installations are rare although no difficulties have been experienced with their operation, and future installations are planned. Because of the many satisfactory installations in the East, it is very possible that capacitors will be used as a means of correcting voltage troubles before other methods are used. Often a comparatively small investment in capacitors makes it possible to defer larger investments for some years to come.

The step voltage regulator has done much to improve voltage conditions in rural areas during the past five years. Because of its low cost and simplicity of operation, it can be used on circuits whose revenue heretofore has not justified automatic voltage regulation. Due consideration should always be given the use of this form of voltage control when voltage problems arise on rural systems.

Coordinated planning

It is apparent that the electric utilities throughout the Northwest are making a creditable showing toward improvement of service in rural areas through the use of modern ideas and equipment. Such use of modern ideas and equipment, however, if not tied in to a well coordinated system plan, may create additional investments which cannot be economically justified.

The utilities should design a model system plan for each area which they serve, looking as far into the future as may be reasonable. Consideration should be given to the use of networks, ties between substations, capacitors, step voltage regulators, common neutral systems, etc.; and all future improvements should be made to fit into this ultimate plan. Such a method of approach will eliminate to a large extent the tendency to allow a system to grow along the lines of least resistance and will ultimately create a system best suited to the needs of the territory which it serves.

Features of Four Typical Northwest Rural Systems

COMPANY NUMBER	1	2	3	4
CLASS OF TERRITORY SERVED	B	A	A, B, AND C	C
Avg Load per Square Mile	9 kw	Not given	Class A—15 to 20 kw " B—10 kw " C— 5 kw	3 kw
Transmission Voltage	45% 66 kv 55% 44 kv	55% 11 kv 45% 24 kv	Rural areas served from urban substations or generating stations	100% 22 kv
Transmission Supply	70% Loop 10% Duplicate 20% Single	11 kv is 100% Single line but can be fed from different substations 24 kv—58% Loop, 35% Duplicate, 7% Single	....	20% Loop 80% Single
Transmission Switching	90% Manual 10% Automatic	100% Automatic	....	90% Manual 10% Automatic
Type of Substation	Outdoor Steel	Steel	....	Outdoor Wood-Pole
Avg Cost of Substation	$15.00 per kw	11 kv—$14.00/kw 24 kv—$12.50/kw	....	$33.00/kw
Automatic Voltage Regulation	90%	80%	Class A—40% " B—20% " C—30%	5%
Distribution Voltages	90% 6.9/11 kv 10% 2.3/4 kv	73% 2.4 kv 25% 7.2 kv 2% 11 kv	Class A—40% 11 kv 60% 6.6 kv Class B— 5% 11 kv 85% 6.6 kv 10% 2.3 kv Class C—60% 11 kv 30% 6.6 kv 10% 2.3 kv	70% 2.2 kv 30% 6.6 kv
Primary and Secondary Networking	None	None	None	None
Primary Ties Between Substations	Yes	Yes	60% in Class A 20% in Class B	No
Automatic Reclosing Switches	Yes	Yes	Used in 10% of lines in Classes A and C	No
Time Delay on Automatic Switches	60% 0-30-75 40% 15-30-60	100% 0-20	12 to 15 Sec	....
Fused Primary Branch Lines	Yes	Yes	Yes	Yes
Use of Fuses on Primary Branch Lines Increasing or Decreasing	Increase	Increase	Increase	Increase
Is Difficulty Experienced in Coordinating Branch Line Fuses with Main Line or Sub. Fuses or Circuit Breakers	Yes	Some	No	Very little
Is Common Neutral Used for Primary and Secondary	Yes	No	No, but is planned for use in future for Class C Territory	No
Is Use of Common Neutral Increasing or Decreasing	Increase	....	....	....
Are Majority of Transformers Used Single or Double Primary Bushing	Single	Double	Double	Double
Kva of Capacitors in Use	235	None	None	None
Has the Use of Capacitors Been Satisfactory	Yes	....	....	....
Are Future Capacitor Installations Planned	Yes	No	No	No

NO Pressure Reducing Valves Mechanical Moving Parts Chemicals

WITH THE OIL-SEALED INERT GAS SYSTEM!

THANKS TO ALLIS-CHALMERS EXCLUsive OIL-SEALED Inert Gas Protection, this bank of six 1,000 kva power transformers needs no frequent oil filtering or constant maintenance.

Systems All Over the Country Take Advantage of Low-Cost Inert Gas Protection. Here's How You Can Cut Your Inspection and Maintenance Costs with Allis-Chalmers Exclusive OIL-SEALED Inert Gas Protection!

IF YOU'RE wasting time and money on pressure type inert gas systems, here are three important reasons why you can cut your costs with Allis-Chalmers exclusive OIL-SEALED Inert Gas Protected Power Transformers!

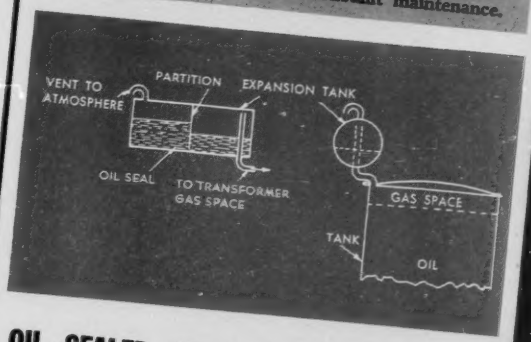
1. **NO PRESSURE REDUCING VALVES!** There's no need to reduce pressures on the OIL-SEALED System. Low operating pressure (almost always less than one pound per square inch) eliminates the need for a complicated set of valves requiring frequent adjustment or replacement.

2. **NO MECHANICAL MOVING PARTS!** The OIL-SEALED System is entirely automatic — no moving mechanical parts to get out of order . . . nothing to wear out.

3. **NO CHEMICALS!** Maintenance costs are slashed with the OIL-SEALED System. There's nothing that requires frequent inspection, handling or replacement.

But that's only part of the story! For all the facts on the many extra value features you get at no extra cost with Allis-Chalmers Power Transformers, write today for Bulletin 1182.

A 1215



OIL-SEALED INERT GAS PROTECTION — HOW IT WORKS

WHEN THE OIL in the main tank expands due to increase in temperature, a slight pressure is exerted on the gas above the oil. This pressure increase is transmitted to one section of the expansion tank causing the oil level to drop in it and rise in the other. The movement of oil in the expansion tank adds volume to the entrapped gas to compensate for the expansion of oil in the main tank, so that the gas space above the oil is isolated from the atmosphere under all operating conditions. The oil in cooling contracts and reduces the pressure on the gas, causing a reverse action to take place automatically.

Over 90 Years of Engineering Superiority Work for You When You Specify Allis-Chalmers!

ALLIS-CHALMERS

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Take this test ON SWITCHGEAR SAVINGS!

Compare

Allis-Chalmers Modern Metal-Clad with Older Types of Switchgear by Asking Yourself These 8 Important Questions!

	Question	Older Type Switchgear	Allis-Chalmers Vertical Lift Metal-Clad	
1	Does it save on floor space?	NO	YES	As much as 50%.
2	Does it take a lot of head room?	YES	NO	Sometimes ¾ amount for older type.
3	Is its appearance attractive enough to harmonize with the rest of the station interior?	NO	YES	And you can select color to match station interior.
4	Are workers fully protected from "live" parts?	NO	YES	Primary and secondary parts are in separate compartments.
5	Is there a complicated wiring diagram to follow during installation?	YES	NO	They're shipped completely wired.
6	Are special vaults or switching structures required?	YES	NO	Just set the units in place and connect the leads.
7	Can the breakers be removed quickly for easy inspection?	NO	YES	Only 2 minutes with automatic operation.
8	Are maintenance costs kept to an absolute minimum?	NO	YES	Complete metal-enclosure keeps dust, dirt out.

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NEAT AND COMPACT— that's the way 24 units of 150,000 kva Allis-Chalmers Vertical Lift Metal-Clad Switchgear would look in your station.

Find out how the longest metal-clad switchgear experience in America can help you cut your operating costs . . . give you added protection for your equipment and your workers! Write for Bulletin B6012.

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